PUBLIC DOCUMENT NO. 29

FIRST BIENNIAL REPORT

OF THE DIRECTOR OF THE

Agricultural College Survey

OF

NORTH DAKOTA

TO THE

GOVERNOR OF NORTH DAKOTA

ORGANIZATION AND ADMINISTRATIVE REPORT

DECEMBER 9, 1902

BISMARCK, N. D.
TRIBUNE, STATE PRINTERS AND BINDERS
1903

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LETTER OF TRANSMITTAL

STATE OF NORTH DAKOTA,
AGRICULTURAL COLLEGE, N. D., Dec. 9, 1902.

Hon. Frank White, Governor of North Dakota, and the Governing Board of the Agricultural College Survey of North Dakota:

Sirs:—I have the honor to submit herewith the first biennial report of the Agricultural College Survey of North Dakota covering its purpose, organization, administration and needs. Your attention is respectfully called to the importance of an agricultural survey in a state where the agricultural features will always stand paramount to all other natural resources; also to the necessary relation of this survey to the work of the state experiment station and the urgent need for a substantial appropriation that will establish the work on a permanent basis and insure a continuation of a liberal co-operation and support from the federal government.

Very respectfully,
CHARLES M. HALL.

REPORT

PURPOSE.

The Agricultural College Survey of North Dakota was organized during the summer of 1901 in accordance with an act passed by the seventh legislative assembly of North Dakota entitled, "An Act Authorizing the Board of Trustees of the North Dakota Agricultural College to co-operate with the United States Federal Surveys, Organized Under the Department of the Interior of the United States, in Completing a Topographic, Agricultural and Geological Survey, as Related to Agriculture, Together with an Economic Map of North Dakota, and Making an Appropriation Therefor."

The organization of this survey is a direct outgrowth of a general plan adopted by the United States federal surveys to make a complete and uniform economic map of the whole of the United States. This consists essentially of surveying first a base map known as the topographic map composed of accurate geographic and political maps—covering areas one minute square, which not only show all natural features, but also by a system of colored lines the altitude above the sea for every twenty feet of vertical interval. Following the preparation of these maps, an accurate survey of the natural resources is conducted and these features represented in a series of colored plates accompanying descriptive texts. Many states early recognized the advisability of the investigation and development of the states' natural wealth when it was represented by the precious metals, coals, oils, or the like; and vast sums have been expended by states in the development of the resources through their state geological surveys. However, it was not until recent years that states like our own, whose resources are primarily agricultural began to realize that there is an equal necessity for showing the natural conditions with respect to our agricultural possibilities, as expressed by the variation and distribution of soils, water supplies and native and introduced fauna and flora.

The federal government has recognized the importance of aiding in developing these agricultural features of our natural resources, and the work has developed so rapidly that within a few short years our

federal government has come to spend an annual sum amounting to hundreds of thousands of dollars in the surveying and mapping of our soils and water resources; in devising means of storing the waters for irrigation, or the preventing of floods; in preserving the forests, and in fostering the growth of native vegetation. But a few years ago the first plans of co-operation were entered Into and a policy established by which the states and the federal government could work together in conducting these surveys. Thus the whole work was unified, the expense of separate organizations was saved and by having all maps prepared at the government printing office, the work was greatly facilitated; more money, too, was spent in the state than could be done if the state should attempt to do the work unaided. This, therefore, has been the purpose of the organization of this survey; to co-operate with the federal surveys and secure their assistance in pursuing the survey of the state, emphasizing the study of those features especially agricultural, water, soil, native forests and other vegetation. Thus from the inception of the survey and its close and necessary relation to the work of the state experiment station, we have adopted as the policy of the survey to confine our work to the topographic survey, and the mapping of the soils, water resources and the general biological survey of the state.

ORGANIZATION AND WORK

According to the above policy plans for co-operation were entered into with several of the federal surveys—all of which have responded freely.

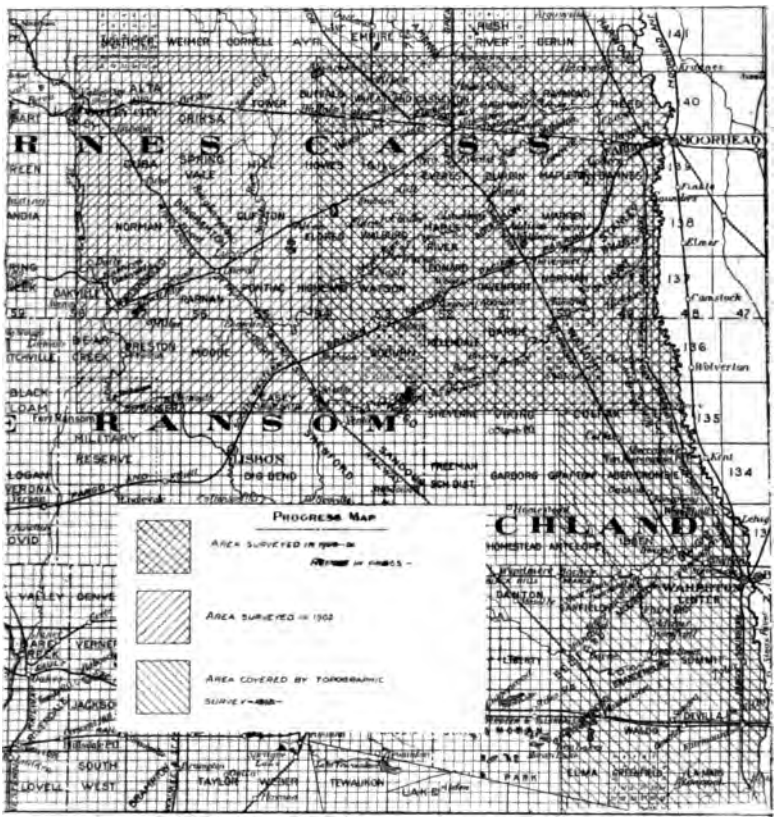
The field work is separated into four divisions: The hydrographic survey, the soil survey, the topographic survey and the biological survey. In addition to these the chemical investigations of the soils and waters are being conducted in the station laboratories, under the direction of Professor E. F. Ladd.

THE HYDROGRAPHIC SURVEY.

The work under this division is separated into two branches, the investigation and mapping of the artesian basins and underground water supplies, and the measurement of the surface or stream waters and their study in connection with the prevention of floods, drainage, power and irrigation.

The work on the artesian basin had been started independently by the United States geological survey before the organization of the state survey and hence it is in a more advanced stage. This work consists in determining the structural geology of the region and the extent, depth, and character of the water supply from both the ar-

tesian basins and pump water horizons. These features will be illustrated in the reports by a series of colored maps which accompany the descriptive text, and which show the topography, the surface and structural geology of the district, the extent and depth to the artesian basins and other water horizons. A bulletin has already been prepared by this division of the work covering the geology and water resources of a portion of southeastern North Dakota. The area covered by this bulletin is shown in the accompanying progress map and



has brought out many interesting features connected with the eastern limit of the Dakota artesian basin in this section of the state, and the surface geology which gives rise to such varying conditions relative to the soils within and along the borders of the Red river valley or the bed of the ancient glacial "Lake Agassiz."

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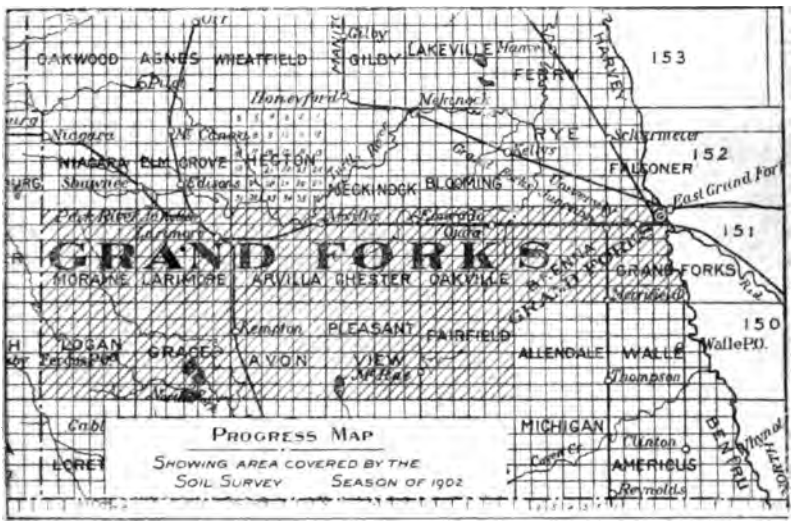
is also kept in Devils Lake, which shows some remarkable fluctuations in recent years and stations are being constructed on the Mouse, Yellowstone, Missouri, Knife, Heart and Cannon Ball rivers.

The data have already been compiled, forming a comprehensive report on the hydrography of the Red river basin, which will go to press this winter.

The total expense of this work has thus far been met by federal appropriations.

THE SOIL SURVEY.

The soil survey of the state was begun during the summer of 1902 in co-operation with the division of soils of the United States department of agriculture. The area selected for the survey was a typi-



cal section across the Red river valley, in Grand Forks county, extending from the Red river of the north to six miles west of Larimore and embracing about 23,000 acres, this area being shown in the accompanying progress map.

Seven types of soil have been carefully mapped, described and studied closely with respect to crop characteristics. A series of maps covering the same area have been prepared showing the percentages of alkali present, which in many cases rise above the amount damaging to many cereal crops. A third series of colored maps show the depth of the natural water table. A bulletin discussing this subject

has been prepared and will soon be issued by the survey and distributed gratis to all in the state who request it.

Mr. C. A. Jensen, of the United States department of agriculture, had charge of the field work during the season of 1902, our own state furnishing his assistants, who are being trained in the work. This is but the very beginning of a work which promises most fruitful results, especially where soil conditions are diverse.

TOPOGRAPHIC SURVEY.

The topographic survey consists of making an accurate political and geographic map of the state in quadrangles, about twenty-five miles wide by thirty-five miles long, each map representing an area of about eight hundred square miles on a scale of two miles to the inch. These maps, besides showing accurately all political features, streams and lakes, railroads, graded roads, towns, etc., also represent by small colored lines the topography of the country or the altitude above the sea for every twenty feet of vertical interval. These maps are invaluable as official maps of reference for all kinds of surveying, and also answer for all preliminary drainage or irrigation surveys, and are used as base maps for all subsequent scientific surveying and mapping. A number of these sheets have already been prepared within North Dakota, but the operations of the federal survey have been directed elsewhere on account of greater demands for the work and more liberal co-operation on the part of other states.

The limited funds at the disposal of our state survey has prevented our offering any substantial co-operation with this division of the federal service. However, from the necessity for more of these maps for use by the other branches of the survey and in the hope of future co-operation on the part of the state, an area covering about 800 square miles has been surveyed in the upper Red river valley during 1902 covering a quadrangle in Richland county, which will be known as the Wahpeton sheet or map, and will probably be ready for distribution during the latter part of the winter.

BIOLOGICAL SURVEY.

The agricultural survey of any region is incomplete without a thorough knowledge of the native vegetation and animal life of the district.

There are several economic features which the biological division of the survey wishes to take up. Among the more important is a study of the grasses and forage plants. Before the areas of this state were put under cultivation, the prairies were covered with lux-

uriant growths of nutritious grasses and legumes In early days these plants provided food for countless herd of bison and more recently the prairies have been the grazing grounds of vast herds of stock. But these conditions are rapidly changing. The tillable areas are coming into cultivation and the grazing lands are being lessened in extent. This course of events is inevitable and is for the general good. But the breaking up of such vast areas of land has an effect upon the native flora that can be viewed only with alarm by conservative men. Many of our most valuable grasses and forage plants are being rendered rare, if not extinct, by such means. It is a fact that needs no argument that our native grass and forage plants are the best adapted for this region. Therefore, any course of procedure which tends to wipe out of existence the valuable native plants is prejudicial to the best interests of our commonwealth. After the virgin prairie has been broken the tendency for the first few years is to crop the land almost exclusively, but our best farmers and the experiment station have concluded that such methods do not pay in the long run. They say that in a few years it will be absolutely necessary—if we wish to keep up our present state of fertility—to seed down our lands occasionally to grasses and legumes. Now, it is the desire of the survey to ascertain the plants which are suitable for the various regions before they become quite exterminated and it is believed that both the farmer and the ranchman can be much benefited by a careful study of the plants in their native regions.

A person traveling over the older cultivated areas of the state and even some of the more newly cultivated portions is struck by the abundance of weeds. It is probably no exaggeration to state that the weeds of North Dakota absorb each year one-tenth of the entire value of the crop. A study of the distribution and relative abundance of the weeds will be a part of the work of the survey, and as a result the experiment station, which will be in close touch with the survey, will be in better position to advise the farmers of the state in regard to the best methods of exterminating weeds, etc.

While the forested area of the state is small, yet its value per square mile, is not diminished on that account. Much of the area covered by timber is ill adapted for farming, if cleared, and if the ground remains covered by forest, the income will be greater than if cleared and used for grazing purposes. It will be the aim of the survey to study the forested areas and to suggest methods of treatment by which they will yield a continuous income. Much of the timber is situated along streams that will furnish power, if demanded, and thus good opportunity is presented for the development of manufacturing industries.

There are many medicinal plants in the state, the distribution and relative abundance of which are comparatively unknown. There is a good demand for some of these plants and the growth of them would be a profitable industry. It will be the aim of the survey to investigate this subject and report upon the methods and feasibility of the cultivation of medicinal plants.

Aside from these more important economic phases the biological division of the survey will study either economic questions as they arise and also make a general scientific study of the plants and animals of the state.

There is now under preparation a revised list of the seed bearing plants of North Dakota, which will be published as a survey bulletin for free distribution as soon as completed.

CHEMICAL INVESTIGATIONS.

I insert herewith an outline of the chemical investigations which are essential to the complete work of the survey and yet from their nature are separate from the work of the experiment station, and must be done at the expense of the survey. This work, however, will be done in the station laboratories at merely the cost of the materials used and the labor of the assistants required.

NEED FOR WATER AND SOIL STUDIES

For the benefit of the farmers of the state one of the great problems that need to be studied is the water supply of the state. The waters of the state show a wide range of difference in the total solids which they contain; also in the character of the mineral constituents constituting these solids. There is a range of from less than two hundred parts per million of total solids to more than 25,000 parts. There is an equally marked range in the character of these solids.

It is particularly important that such an investigation be undertaken before much is done in irrigation. With a soil already heavily charged with soluble salts it is a matter of the greatest importance to know the character of the water to be used for purposes of irrigation. The supply of water for irrigation purposes must be derived from one of the following sources:

1. The rivers and streams.
2. Stored flood water.
3. Artesian wells.
4. Surface wells.

The waters from the third and fourth sources will have a wider range of use than those from the other two sources. The artesian

well water of the state contains from about five hundred parts to 25,000 parts per million of solids. The artesian basins of the state need to be well defined and the waters carefully analyzed; then we shall know what to expect to find in several localities and to what extent those waters can be employed in agriculture. It is of equal importance that this systematic study be made in order to know what waters are suitable for domestic use, and again for the supplying of animals with drinking water. Some of these artesian waters are known to be so charged with alkaline salts and with glaubers or epsom salts as to be injurious to animals drinking the same, particularly horses, which are more susceptible than are cattle.

The waters in the surface wells vary even more than the artesian waters and for like reasons the waters from surface wells should be analyzed and classified into areas of like composition.

The chemical department is already in possession of a large amount of data which could be utilized in a systematic survey; but at present the data are useless except for individual cases.

SOIL STUDIES.

No study or classification of soils can be complete that does not take into consideration their chemical composition. Any agricultural survey to be made should include the chemical studies necessary for a full knowledge of the composition of the soils of the state; then the areas of like composition can be outlined with great value to the future agricultural development of the state. To know the soil of the state is to know the future possibilities of the state's agriculural development. Without systematic knowledge all advances are made at great sacrifices of time and wealth. Why should we not know the soils of our state as we know its fauna or flora? A knowledge of one is not complete without a knowledge of the other. If one is a benefit to a commonwealth, then the others must be. Are the soils of the state all uniform in composition? If not, are there areas of like chemical and physical properties? If so, to know such areas is to know what these soils are deficient in and wherein they need to be supplemented with plant food. It enables us to intelligently judge of the kind of crops best adapted to be grown upon these soils. A knowledge of the soils of the state such as I have indicated would be if incalculable value to the state in the use of fertilizers alone. It may be safely said that millions of dollars are spent each year in this country for commercial fertilizers that are not needed to produce good crops. If we knew the composition of our soils, the needs of plants in the way of plant food, and knew how to conserve plant

food in the soil, and how to reserve plant food available, we should be able to add many millions of dollars to the wealth of our state and yet leave a soil more productive than the one with which we began. A knowledge of the chemistry of our soils would make such a thing possible.

E. F. LADD,
Chemist.

PLANS OF WORK, ADVANTAGES, COST.

The chief object in the organization of this survey is to effect a co-operation between the state and the federal surveys for the purpose of securing their aid in "executing a topographic, economic and agricultural survey and map of North Dakota." In arranging the details of co-operation with the federal surveys the law directs that the federal surveys "thus co-operating with the state of North Dakota shall agree to expend on the part of the United States upon said work a sum equal to that appropriated by the state of North Dakota for that purpose."

The limited amount of money at the disposal of the state survey was almost insignificant as compared with the cost of starting the different branches of work undertaken, which in several instances has been borne entirely from the federal funds. This work has been established with the expectation that the state, when it sees the advantages of this organization will come to a substantial co-operation in the future. It is the plan of the survey to select at the beginning of each season, definite areas for work and to complete these as soon as possible, publishing the results with maps, etc., as bulletins for free distribution, and to avoid as much as possible that general or preliminary work which requires future duplication. Arrangements have been made with the different federal surveys whereby the colored plates, maps and engravings are to be made at the government printing office and these are to be used by the state at the mere cost of printing. While this necessitates some delay in the issuing of bulletins, it is compensated by the great saving to the state and the high quality of workmanship produced.

Bulletins will be issued from time to time as each branch of the survey completes its work over a given area and as the survey of each county is completed final reports by counties will be published. Already several bulletins are completed or will go to press this winter; their publication is now being deferred, awaiting the preparation of the maps at the government printing office.

The above bulletins cover the following subjects:

(1) "The soils of a typical section of the Red river valley embraced in Grand Forks county, N. D."

(2) "The hydrography or water resources of the Red river valley."

(3) "The surface geology and artesian basins of a section of southeastern North Dakota."

In addition to these the biological division is preparing a revised list of the seed bearing plants of North Dakota and the chemical division is at work on the chemistry of soils and waters of the areas surveyed.

The expense of the work done under the survey during the last biennial period is as follows:

Topographic survey of the Wahpeton quadrangle	$ 2,500.00
Hydrographic survey including stream measurements...	1,824.26
Field work soil survey 1902........................	1,324.07
Apportionment for biological survey.................	100.00
Apportionment for chemical work...............	100.00
Miscellaneous expenses............................	400.00
Total	$ 6,248.33

Of this sum, exceeding six thousand dollars spent principally within the state during the past two years, the state has furnished less than one thousand dollars or only about one-sixth of the total amount.

A record of the disbursement of the state funds through the survey is kept by a system of vouchers and sub-vouchers covering all items of expense and audited by a member of the board of trustees, the books always being open for inspection.

PRELIMINARY ECONOMIC MAP OF NORTH DAKOTA.

Since the organization of this survey the number of inquiries received by parties both in our own and neighboring states relative to the economic resources of North Dakota, more especially to the extent of the Red river valley, the artesian basins, our annual precipitation, etc., have drawn heavily upon our time in collecting the data and in making replies. After consultation with the governor and commissioner of agriculture it was decided to combine a preliminary geologic and economic map showing the present extent of our knowledge of these features with our official state and railroad map for a general distribution. This map which accompanies the report not only fulfills a great demand for more general knowledge of the econ-

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Agricultural College Survey of North Dakota

TO THE

Governor of North Dakota

ADMINISTRATIVE REPORT AND ACCOMPANYING PAPERS FOR THE YEARS 1903-4

DANIEL E. WILLARD
Director

BISMARCK, N. D.
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DIVISION OF SOILS.

REX E. WILLARD, Assistant.
JOHN T. WEAVER, Assistant.

DIVISION OF CHEMISTRY.

ARTHUR G. NICKLES, Assistant Chemist.

CONTENTS

LIST OF ILLUSTRATIONS

LETTER OF TRANSMITTAL

To Hon. Frank White, Governor of North Dakota, and the Honorable, the Governing Board of the Agricultural College Survey of North Dakota:

SIRS: I have the honor to present herewith the second biennial report and accompanying papers of the Agricultural College Survey of North Dakota, including the work of administration and the field operation for the biennial period of Nineteen Hundred and Three and Nineteen Hundred and Four. My connection with the Survey as director dates from the first day of April, Nineteen Hundred and Three, on which day the duties of instructor in the Agricultural College were assumed, and therewith, as required by the law organizing the Survey, the duties of Director of the Agricultural College Survey of the State.

The organization and administration of the Survey had been so well done by my lamented predecessor, the late Professor Charles H. Hall, that the successful progress and carrying forward of the work seemed but to require the continuation of the plans which had been outlined and the carrying on of the work which had been begun.

As agriculture is now and seems destined by Nature to be an industry of unequalled importance in this state the vital value and importance of a survey having the varied phases and departments of agriculture for its aim and purpose would seem to be apparent. Recognizing the importance of a scientific study of those subjects most fundamentally connected with agriculture, the Seventh Legislative Assembly authorized such a survey, and by the provisions of the act of organization constituted you its guardians and sponsors. Acting under your authority, therefore, I present you herewith a report which attempts to show what work has been undertaken, and the needs of the survey in order that its usefulness may be enhanced and realized.

Your honorable attention is respectfully called to the great discrepancy between the amount appropriated by the state for this

co-operative survey and that expended by the federal government for surveys within the limits of the state, the latter being fully five times the amount of the former. Attention is thus particularly directed to this fact because it has been adopted as the working policy of the general government to expend money for surveys in those states where money is also furnished for such surveys by the state, and it is the policy to expend an amount equal to that expended by the state. It is therefore obvious that it is greatly to the financial interest of the state to meet the cordial co-operation offered by the federal government with a fair consideration. In the following pages of the administrative report the needs of the different divisions represented by the survey are set forth, and a careful consideration of the facts is earnestly requested.

Very respectfully yours,

DANIEL E. WILLARD,

Director.

ADMINISTRATIVE REPORT

THE SECOND BIENNIAL REPORT

OF THE

AGRICULTURAL COLLEGE SURVEY

OF NORTH DAKOTA

BY DANIEL E. WILLARD, DIRECTOR.

Plan and Purpose of the Survey.—The purpose of the Agricultural College Survey is indicated by the title of the law organizing the survey, viz: "An act authorizing the board of trustees of the North Dakota Agricultural College to co-operate with the United States Federal Surveys, organized under the department of the interior of the United States, in completing a topographic, agricultural and geological survey as related to agriculture, together with an economic map of North Dakota, and making an appropriation therefor."

In a state in which the welfare of so great a percentage of its citizens is directly related to agriculture it is of the greatest importance that every avenue leading to the more perfect development of the resources of soil and water supply should be followed up. The Agricultural College and Experiment Station is a natural center from which many important investigations, touching upon the various phases of agriculture, would take their origin. The relations of the structure of the earth below the surface to the water supply and the rock-character of the soils to crop production are such that the investigations of the biologic, chemical and agricultural divisions of the experiment station must necessarily be intimately associated with the work of a geological survey.

Organization and Working Methods.—While in its character the Agricultural College Survey is co-operative with the United States Federal Surveys, yet it is independent in the management of its finances. For all expenditures for subsistence in the field, salaries for services or the purchase of materials sub-vouchers are taken, following the very accurate and perfect system employed by the United

carried on in different parts of the United States. It is only possible to present with this report an incomplete description of the results that have been accomplished in this state in these investigations. The results are being elaborated and will be published with full descriptive text and colored maps in folios of the United States Geological Survey. Portions of the text of the Fargo-Casselton folio, now in press at Washington, are by permission of the authorities of the federal surveys included in the accompanying papers of this report. Some of the results also of the underground water investigations in the territory embracing all or portions of the counties of Cass, Barnes, Stutsman, Richland, Ransom, Sargent, LaMoure and Dickey are included in the accompanying report.

Topographic Survey.—During the summer of 1903 a survey was made by the United States Geological Survey for the purpose of establishing primary control preparatory to the detailed topographic survey on the two quadrangles lying north of the Fargo and Casselton quadrangles. The completed topographic map of these areas will be made another season. After the topographic survey has been completed the areal geology and underground water investigations will follow.

Survey of the Coteaus of the Misouri.—The Agricultural Survey has undertaken the completion of an important bit of mapping in the western portion of the state in the region known as the coteaus of the Missouri.

The coteaus are really glacial, or morainic, hills, and constitute the outer of the series of terminal moraines which were formed at the edge of the great ice sheet during the closing stages of the glacial period. The hills in this region form a portion of a vast system which extends from far north and west in Canada in a southwesterly direction across North Dakota and South Dakota, thence in a generally easterly direction across the continent to the Atlantic ocean.

No accurate map of that portion of this great moraine lying in North Dakota north and west of the main line of the Northern Pacific railway between Jamestown and Bismarck to the international boundary at the northwest corner of the state has ever been made. More or less detailed and complete maps of this great moraine have been made in other states, but not before in North Dakota.

This region embraces one of the great grazing domains of the state. The system of morainic hills and attendant deposits within the state embrace an unmapped tract varying from twenty to fifty miles in width and 200 miles in length. This region has within the past few years been in part occupied by settlers who desire to pursue general farming. A large part of this great tract is still open to homestead entry. Considerable tracts of these lands are better adapted to grazing than to general farming.

The survey had a twofold purpose in undertaking the preparation of an agricultural-geological map of this portion of the state. First, it was deemed of great importance to the state that the character and adaptability of these lands to farming and grazing should be made known, for the benefit of homeseekers and in the general interest of the development of the resources of the state. Second, it seems highly desirable that a map of the portion of the great continental moraine lying within the territory of North Dakota should be systematically and correctly mapped. All other portions of this great moraine have been mapped, from the Missouri river in South Dakota to the Atlantic ocean. Accordingly what has been called an agricultural-geological survey has been undertaken, and a party consisting of four men was placed in the field in July, 1903. Minot was the railroad point from which operations were conducted, and a field camp was first established about thirty miles south by southwest of Minot, in township 152, range 54. The party consisted of the director, two assistant geologists, a soil specialist, and for a part of the time a biologist, who gave attention to the native grasses of the region. A map showing the area surveyed and a descriptive report of the investigations made will be found with the accompanying papers of this report.

Biological Survey.—A biological survey of the state was contemplated in the organization of the Agricultural College Survey, the purpose being to make a thorough and systematic study of the native grasses and other useful and injurious plants, and to determine as far as practicable the value and detriment respectively of these. The study of the native plants gives a key to the cultivated varieties that can be best grown under given conditions of soil and climate. The plants of any region are so intimately associated with the soil and other geologic conditions that a biological survey and a geological survey naturally supplement each other.

The limited funds available for the work of the Survey has rendered it impracticable to do anything more than the merest preliminary work looking toward the ultimate completion of the biologic division of the economic map of the state.

Progress in the Division of Chemistry.—Owing to the limited finances it is possible to report only a comparatively small amount of progress made in the chemical investigations of the waters and the soils of the state in proportion to what the importance of the subject demands. What has been accomplished has been through the chemical laboratories of the college and by those regularly engaged in chemical work, under the direction of Professor E. F. Ladd. Owing to the large demands upon Professor Ladd's time for other chemical investigations and to the crowded condition of the college laboratories, it has been impracticable to attempt the systematic classification and analysis of soils and waters that had been contemplated.

FIELD OPERATIONS, 1904.

Soil Survey.—During the season of 1904 a very thorough and detailed soil survey was made in southern Towner county, Cando being headquarters for the party. Two experts were sent from the Department of Agriculture, bureau of soils, on July 1st, and they spent the months of July, August and September in this field. Another survey was made in Ward county, near Minot, by a soil student from the college. Reports of these surveys accompany the present report.

The survey in Towner county was conducted by Mr. E. O. Fippin and Mr. J. L. Burgess, trained soil specialists. In order to facilitate the work and give the state the largest possible benefit of the liberal treatment extended by the federal authorities, two assistants were sent from the college, thus making it possible to extend the investigations over a larger territory than would otherwise have been possible. Two parties or sections were organized for the conduct of the field work, a specialist and an assistant constituting each party.

The only expense incurred on the part of the state for this work was the salary and expenses of the two assistants, all expenses for livery services for both parties being borne by the bureau at Washington.

A survey covering an area of two townships situated near Minot in Ward county was made by Mr. Rex E. Willard. This survey was undertaken because of the importance of this region as a newly-developed agricultural region. The territory selected lies in part on the bottom of the ancient glacial Lake Souris and in part on the higher land which bordered the lake on the west.

Areal Geology and Underground Waters.—During the summer of 1904 the investigations which were in progress during the preceding season were continued under the auspices of the Division of Hydrography, United States Geological Survey. The detailed study of the Eckelson quadrangle, lying between Valley City and Jamestown, was carried on by the writer and Mr. H. V. Hibbard. A full report, including colored maps and descriptive text, will be published by the United States Geological Survey as a folio.

Survey of the Coteau of the Missouri.—The survey in the coteau region, commenced in 1903, was continued in 1904, as much being done as the funds available would allow. It was necessary to discontinue the work in this field before the close of the seaosn owing to the fact that the funds had been exhausted.

During the seasons of 1893-4 an extent of territory embracing about sixty townships has been mapped, and a map of the region traversed, and a descriptive report on the character of the lands accompanies this report.

Topographic Survey.—A topographic surveying party was sent from Washington, which was engaged the entire summer in the preparation of a topographic sheet embracing portions of Richland, Ransom and Sargent counties, and known as the Wyndmere sheet or quadrangle. The entire expense of this work was borne by the federal government, the state survey having so meager an amount to offer for co-operation that it was declined and the entire expense borne as above mentioned.

It may be proper to explain here that it is the policy of the federal government to expend each year in such surveys an amount equal to that appropriated for this purpose by the states. It will thus be apparent that if this work is to be continued in our state it will be needful to offer a sum for co-operation comparable to that offered for such work by other states.

A word regarding the character of the topographic survey and the areas that have already been surveyed may not be out of place

here. First, the topographic survey forms the basis for all further detailed surveys. The progress of all systematic work in the state will therefore be determined by the attitude that is assumed in regard to topographic work. If the state offers liberal co-operation in these surveys, this will render possible the more rapid advancement of the work along more strictly geological and economic lines. Moreover, the interest shown in the progress of the work by the state itself lends encouragement to the federal government that will naturally lead to continued co-operation in the surveys which have been already begun, and for the conduct of which the federal surveys have expended so liberal sums.

A topographic map or sheet covers an area of one-fourth of a degree of the earth's surface, a quadrangle as the area is called, being bounded by parallels and meridians, respectively thirty minutes of arc of the earth's surface apart. In this latitude a topographic sheet or quadrangle is about twenty-four and one-half by thirty-four and one half miles in extent and embraces an area of a little less than 850 square miles.

On the topographic map or sheet the elevation of every part of the area is shown, also all the lakes and rivers and smaller streams, towns, railroads, public highways and houses. The maps are printed on a scale of one-half inch to the mile. This makes each section of land appear on a scale suitable for further detailed studies.

Ten topographic sheets have thus far been made in North Dakota, which are designated as follows, the name being derived from the principal town centrally located on the quadrangle: Fargo, Casselton, Tower, Eckelson, Jamestown, Pingree, Wahpeton, LaMoure, Edgeley and Wyndmere (the last named having been surveyed in 1904.)

Biological Survey.—Owing to the limited state of the survey finances it was deemed best not to attempt any further study of the native grasses and forage plants until funds should be available sufficient to carry on the work adequately and fully enough to make it possible to reach some definite conclusions.

Chemical Survey.—Arrangements were planned to have a chemical survey made of the region about Devils Lake, and the lakes in the adjacent portions of the state, but the funds were found to be insufficient to carry the work to adequate completion, and the effort was abandoned for the present season.

The purpose of this survey was to determine from analysis of soil samples taken from the different soil types in the region, and from analysis of water from Devils Lake and the lakes and streams of the neighborhood, what is the relative percentage of salts and alkalies in the soils and waters of the region as compared with the waters of Devils Lake. This would give a basis for determining the cause of the saltness of Devils Lake, and also a key to the best treatment of lands in which salts and alkalies are found.

The Personnel of the Survey.—The state has been fortunate in securing the services of young men of so high a degree of special fitness and training for the various lines of investigation represented. It has been, and will continue to be the aim of the Survey, to interest young men from our own state in the work of the Survey. It is hoped that trained men may ultimately be secured from our own state who will be able to conduct the highest class of investigation. Several young men from the Agricultural College and other institutions have been engaged upon the different lines represented by the survey. It is hoped that of this number at least some will find a congenial atmosphere in the domain of geology, and will become professional workers in this field. Such men are in demand both by the state and the United States, and it seems fair to presume that there will continue to be an increasing demand for such trained experts as the development of the resources of the state continues and the importance and value of accurate scientific investigations becomes more fully realized.

The state has been particularly fortunate in securing the services of Mr. H. V. Hibbard, as assistant in the department of areal geology and underground waters. Mr. Hibbard was for several years a student in the department of geology of the University of Chicago, and now professor of geography in the Hyde Park high school, Chicago. His preparation for the accurate work of the department he has represented has been of the highest order, having had the benefit of training under the direct instruction of the foremost geologists in America. His experience in practical field methods therefore renders his services of the greatest value. By reason of Mr. Hibbard's assistance it has been possible to extend the work in this department beyond what would otherwise have been possible.

Cost.—The amount appropriated by the last legislative assembly for the maintenance of the Agricultural College Survey was $2,-000. As the Survey was organized to co-operate with the federal surveys, the amount made available by the state would naturally determine the amount of co-operation into which the federal surveys would enter, and the amount also which the state desired. However, the federal authorities have taken good will at its full value, and have expended a much larger amount than the state appropriated in the hope that more active co-operation on the part of the state would be provided for when the next legislative assembly should convene. The aggregate expended by the federal surveys in co-operation with the Agricultural College Survey in the divisions of soil, areal geology and underground waters, and topography is upwards of $10,000 for the years 1903-4, aside from the cost of the publication of reports.

It can hardly be hoped that the federal authorities will continue to expend funds so generously in our state unless some active appreciation of the generosity manifested be shown by reasonably adequate provision of funds by the state.

Needs of the Survey.—So urgent is the demand for adequate funds and so great the value of the work to the state which has been begun and thus far carried on principally at the expense of the federal government that I desire most respectfully to call your attention to the needs of the several divisions represented by the Agricultural College Survey. The topographic survey forms the basis for all further detailed surveys. The cost of making a topographic map averages about $3,000. The policy of the government is to expend in each state an amount equal to that provided by the state itself. In order to have the topographic survey progress with rapidity and in accord with the general progress of the work in other lines, one sheet at least should be prepared each year. Thus the state in order to meet the generosity of the federal government should provide $1,500 per year for this work.

Similarly, the work of the soil survey has been heretofore done almost entirely by the federal department, but in the hope that the state would realize the benefit and value of the work and provide an annual sum sufficient to meet that offered by the federal government. For this work the federal government has expended during the past two years about $3,000, or $1,500 per year.

The division of hydrography of the United States Geological Survey has expended about the same amount annually.

In addition to the lines of co-operative work above mentioned the Agricultural College Survey has, in conformity with the purpose expressed in the law organizing the survey, undertaken to complete an economic and geologic map of the state. As a part of this work the survey has undertaken the preparation of a map showing the different characters of lands, the soils and waters, also the native grasses and forage plants, in the western portion of the state—a portion of the state, as has been stated before, that has never been accurately mapped—looking toward a more complete geologic and economic map of the state. For this work $1,000 per year is needed.

I would also most respectfully urge the necessity of provision of sufficient funds to maintain the chemical and biological divisions of the survey, and also to provide for permanently preserving specimens of soils, rocks, minerals and other material, such as is being collected each year, but for the preservation of which no adequate provision has been made.

The investigations which are contemplated in the division of chemistry include both field studies and laboratory analyses. Five hundred dollars per year for the biennial period will be needed to carry to satisfactory completion the field and laboratory investigations which it is hoped to undertake, $300 being the estimated necessary cost of the field work, and $200 that for laboratory materials, and the services of competent assistants.

For the biological survey and the preservation of material collected in the work, $500 per year ought to be expended in order to yield the best results.

In the interest of the fullest conservation of the results of the survey, I would recommend that suitable cases for the preservation and storage of the valuable material which is each year collected by the different field parties be made. One hundred dollars per year would make it possible to preserve each year material representing a value for educational purposes and the work of allied departments of the college almost beyond expression in figures.

Summarizing the above figures, I desire to recommend the appropriation of the following amounts, to be used in the discretion of the director for the following purposes:

OBJECT FOR WHICH USED	ANNUALLY
For topographic survey	$ 1,500
For soil surveys	1,000
For survey coteaus of the Missouri ..	1,000
For division of chemical investigations	500
For biological survey	500
For preservation of material	100
For director's expenses and incidentals	400
Total for all purposes	$ 5,000

Charles Monroe Hall.

ACCOMPANYING PAPERS.

THE LIFE AND WORK OF PROFESSOR CHARLES M. HALL.

By Warren Upham, St. Paul, Minn.

From the American Geologist, April, 1902.

In the comparatively new states west of Minnesota, resident geologists are few. Many problems of theoretic and economic geology wait there to be worked out. The death of a young geologist, who was well equipped and earnest for this work, who had grown from boyhood to manhood in North Dakota, whom to know was to esteem and love, is therefore a great loss, not only to his personal friends, but to the wider interests of education and science.

Charles Monroe Hall was born in Wellington, Ohio, October 21, 1870. When he was about twelve years old, his parents and the family removed to North Dakota (then a part of Dakota Territory), settling in Stutsman county, near the present town of Eldridge. Later they removed to Grand Rapids, on the James river in LaMoure county, where they engaged several years in farming. In 1891 his parents removed to the state of Virginia, where they have since resided. Charles, however, preferred to remain in North Dakota, entered the State Agricultural College at Fargo, went through the usual course of four years, and was graduated in 1895, with high honors.

Immediately after his graduation, he was appointed assistant professor of chemistry and geology in that college, where he taught during the next two years. To better qualify himself for his duties there, he then obtained a leave of absence for a year of special studies in Johns Hopkins University.

Frederick Bennett Wright, his room-mate during this year at Baltimore, writes: "In the autumn of 1897 Mr. Hall entered the graduate department of geology. His enthusiasm in the work,

together with his attractive personal characteristics, soon won for him a genuine popularity within the circle of geological professors and students among whom he had come. Although his interest in the work before him was general, he was more attracted by structural and physiographic subjects than by those of mineralogy and paleontology. His life at Fargo, in the old bed of lake Agassiz, naturally gave him a keen interest also in glacial geology. During his stay at Johns Hopkins, he worked for a short time on the Maryland Geological Survey, along the Potomac river. There his work was so thorough and satisfactory that he was offered a position in that state survey, for field work on the coastal plain the following summer. But his teaching and plans for field work in North Dakota were more attractive and caused him to return there. Personally he was very modest about his accomplishments, but yet had a sufficient sense of their importance to give him the confidence in himself necessary for success. I was greatly impressed with his broad views on all subjects, and his wide interest in general topics. We often had heated discussions, though perfectly friendly, which sometimes lasted till after midnight, on all conceivable subjects, from geology, evolution, and theology, to music and art."

Returning in the summer of 1898 to the Agricultural College of North Dakota, and being promoted to its professorship of geology, Hall was constantly engaged, through the remaining four and a half years of his life, in his duties as a college instructor, including frequent excursions with his classes, and in more extensive examinations of distant parts of the state during vacations.

In the summer of 1900 he began a systematic investigation of the artesian wells and underground water resources of North Dakota, through cooperation by the Agricultural College with the United States Geological Survey. Previously also he had aided Professor J. E. Todd, during one or two summers, on similar work in a part of the James river valley in South Dakota.

Besides the hydrographic work, he began at the same time a survey of the soils of North Dakota, being associated with F. H. Newell and Milton Whitney of the U. S. Geological Survey, in their respective departments of hydrology and soil investigations. Manuscript reports and maps, notes of stream measurements, records of artesian wells, collections and analyses of soils, etc.,

relating to parts of these researches already completed or well advanced, had been forwarded to Washington, but they still await publication.

Professor Hall had presented some of the results of this work in a series of newspaper articles, concerning the water supply of Fargo, the artesian basin and wells of the Red river valley and westward, irrigation for the drier western parts of the state, and the capabilities of its different regions for agriculture and grazing, these articles being published in the Fargo *Forum and Daily Republican,* the Wahpeton *Gazette,* the Minneapolis *Journal,* and other newspapers, during the years 1900 to 1902.

One of the most important of these contributions is entitled "A Discussion of the Water Resources of Fargo and Vicinity, with Special Consideration of Possible Sources of Water for a Better Supply for the City," which filled four columns of the *Forum,* June 24, 1902. It is accompanied with a section across Red river valley, on the line of the Northern Pacific railway, and a map which shows the limit of the chief artesian basin, receiving water from the Dakota sandstone, and the smaller areas of the valley receiving usually scantier flows from the drift deposits.

Within the last month before his death, he completed a manuscript for the supplement in a school geography to be published by the American Book Company, this supplement being a "Geography of North Dakota."

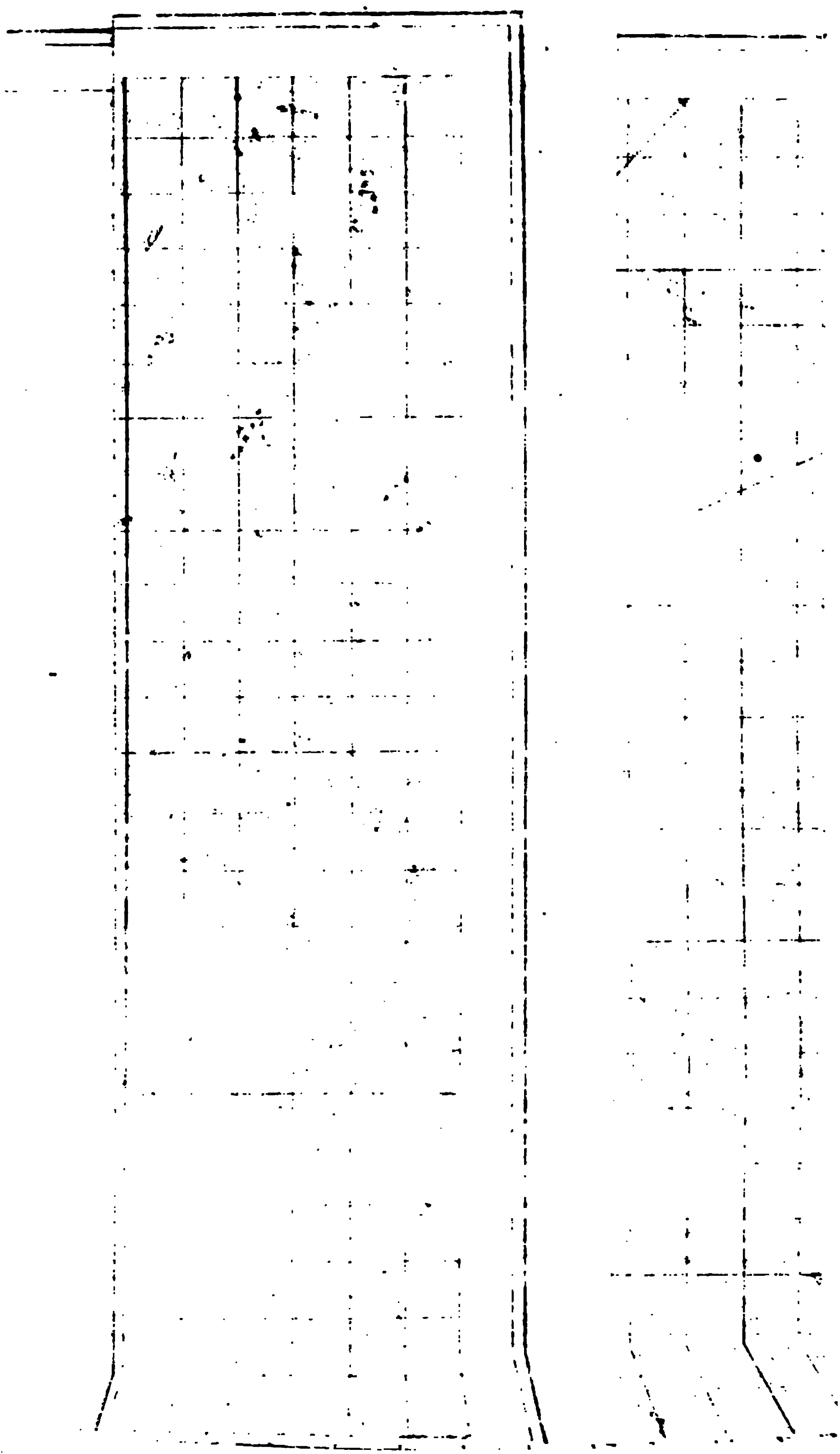
Professor Hall represented his state through appointment by the governor, in the Tenth National Irrigation Congress, held at Colorado Springs, October 6 to 9 of last year; and in the Fargo *Forum* of November 22 he published a considerable report of its proceedings, with earnest recommendation that North Dakota should take a larger share, in connection with the U. S. geological and hydrographical surveys, for the development of irrigation.

The latest and perhaps the most important work which Professor Hall brought to completion and publication, as printed in December, 1902, is an "Official State Map and Preliminary Geologic and Economic Map of North Dakota, issued by the Agricultural College Survey * * * in cooperation with the U. S. Geological Survey; approved by Frank White, governor of North Dakota, and R. J. Turner, commissioner of agriculture and labor." The scale of this map is seventeen miles to an inch. The western half of the state,

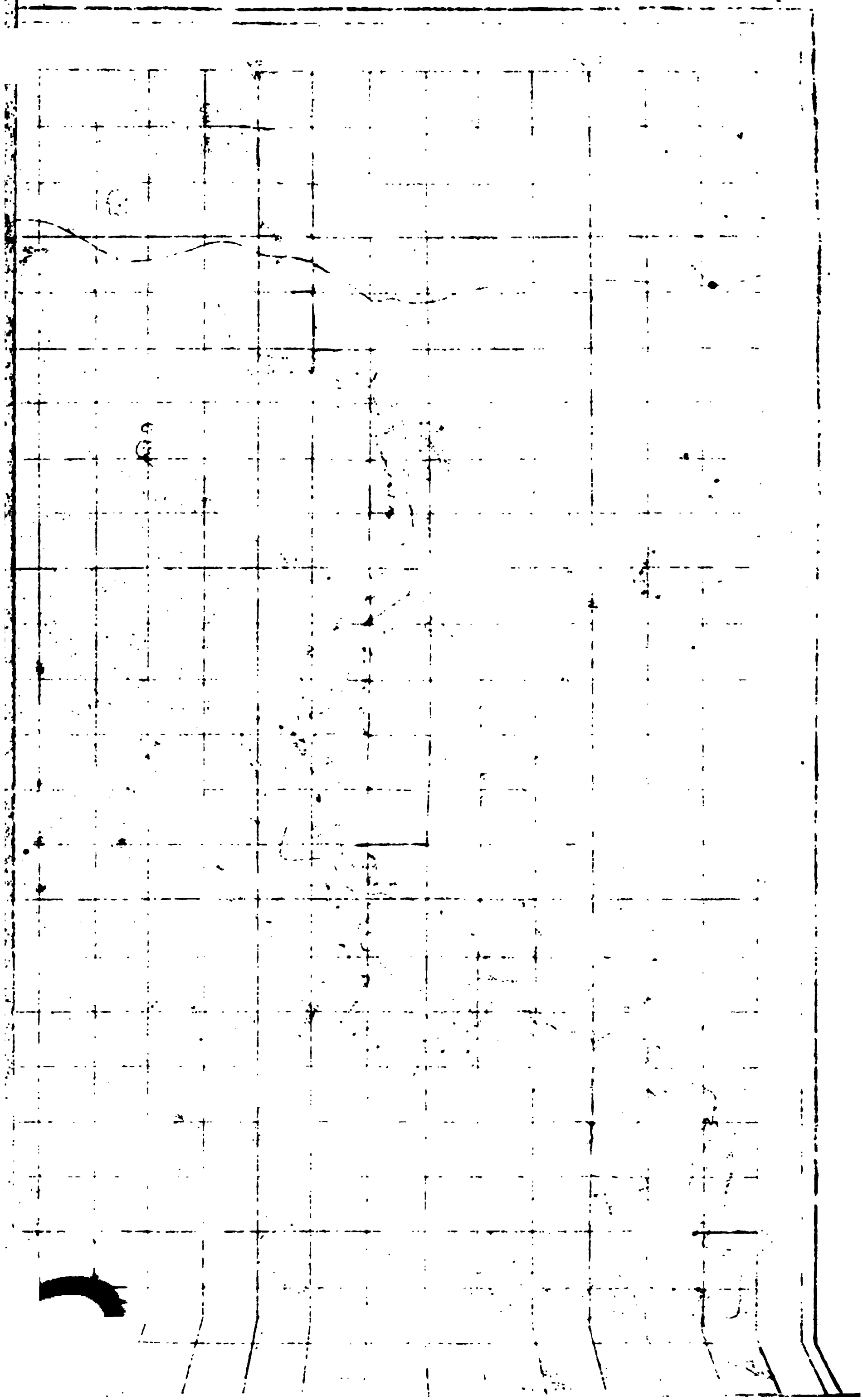
and the Turtle mountains, are colored as Laramie clays and shales, with many outcrops and mines or openings of workable lignite. Thence eastward the remainder of the state, excepting the area of the glacial lake Agassiz, is colored as glacial drift overlying the Montana shales of Upper Cretaceous age. Upon these colors the courses of the marginal moraine belts are shown by another color printing. On the eastern border is the part of lake Agassiz west of the Red river, with its large Sheyenne, Elk Valley, and Pembina deltas. The extreme limit of the glacial drift, and the boundaries of the Dakota artesian basin, are designated approximately.

October 22, 1901, Professor Hall was married to Miss Jessie E. Taylor, of Fargo, and their life together was one of remarkable happiness and mutual helpfulness. They both were members of the First Methodist Episcopal church of Fargo, and of its choir. Professor Hall was also a member of the Masonic fraternity, the Knights Templar, and other social organizations.

His last illness was diagnosed by physicians, half a year before he died, as probably to prove fatal within a year, or, at the longest, a few years. Yet he courageously continued his teaching and his plans for the state agricultural survey. One of his last pieces of work was to frame a legislative act giving to that survey, as aided by that of the United States, a distinct field not duplicating the work of the State Geological Survey, which is in progress under the auspices of the State University and School of Mines of North Dakota, at Grand Forks. His work of instruction in the college was continued until only three days before his death, which occurred at his home in Fargo the 22d of January, 1903. For him is the divine promsie, "Be thou faithful unto death, and I will give thee a crown of life."



NORTH DAKOTA GEOLOGICAL SURVEY



A SURVEY OF THE COTEAUS OF THE MISSOURI.

BY DANIEL E. WILLARD AND M. B. ERICKSON.

What the Coteaus Are.—A great region lying east of the Missouri river was called by the early French explorers "Les Coteaux du Plateau du Missouri," or The Hills of the Missouri Plateau. In the popular mind the hills or "coteaus" and the plateau are confused, the term "coteaus" being often applied to the great hilly upland which is the plateau, and a surface feature of which is the "coteaus" or hills. We shall therefore attempt to make clear the relation of the "coteaus" to the plateau.

"Les Coteaux du Plateau du Missouri" may be briefly and for convenience styled the coteaus of the Missouri, or the Missouri coteaus. Les Coteaux des Prairies, from which the former should be carefully distinguished, is another and quite distinct feature of the landscape of the states of North and South Dakota. The latter is an immense hill many times larger than any one of the Missouri coteaus, lying mostly in northeastern South Dakota but extending across the border into North Dakota near Havana and Lidgerwood. Le Coteau des Prairies is a large preglacial hill having its surface covered with a mantle of drift hills much like the coteaus of the Missouri only not generally as large. The coteaus of the Missouri are morainic hills.

Le Plateau du Missouri, or the Missouri Plateau, is a vast upland of preglacial origin. The eastern edge of this upland extends across North Dakota in a generally northwest and southeast direction. The front rises quite abruptly from the plain to the east from 300 to 400 feet. This steep slope or front appears west of Ellendale, Edgeley, Jamestown, Carrington, Fessenden, Minot and Portal, distant from these places twenty to thirty miles.

This plateau it has been stated is a preglacial landscape feature. It was not in any manner formed by the ice of the glacial period.

Lying on the top of the plateau is a great belt or tract of hills, drift hills formed by the action of the great ice sheet during the glacial period, which together make up what is known as a moraine.

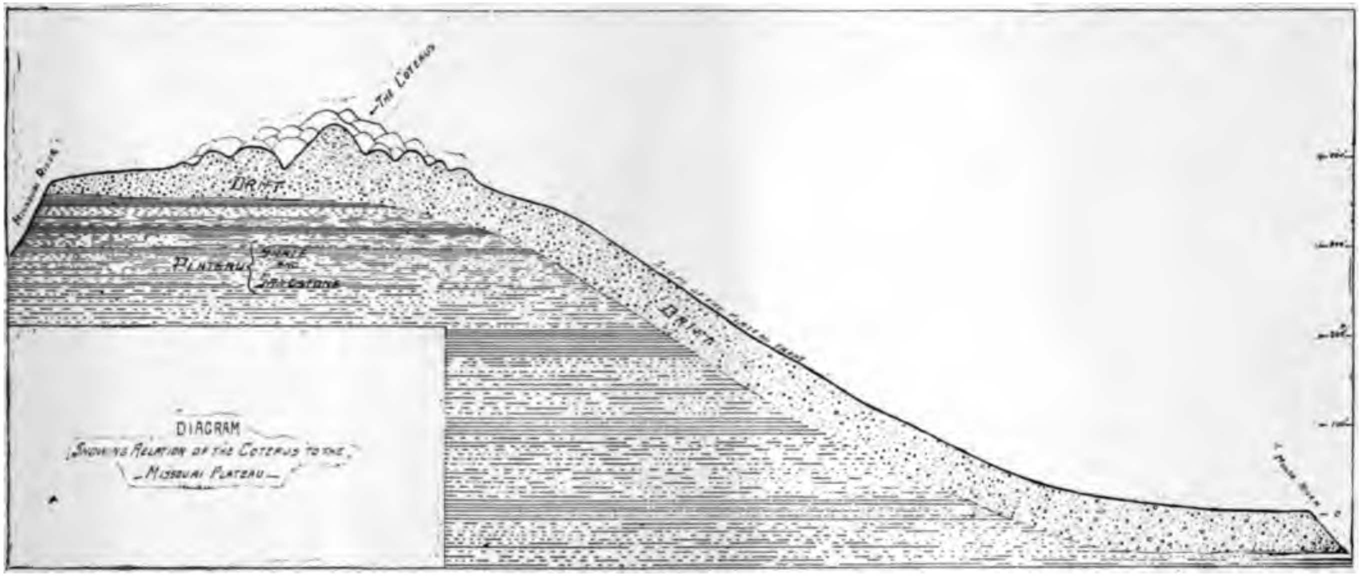
This moraine in North Dakota is a portion of the great continental moraine which was formed during what is known as the Wisconsin stage of the great ice age. This moraine extends across the continent from the Canadian northwest territories to the Atlantic ocean. The moraine in North Dakota is no more a part of the great Missouri plateau than is this same moraine in Pennsylvania a part of the Allegheny mountains. The moraine is a deposit of earth materials—stones, clay, sand, and soil—ploughed up and transported by the great moving ice sheet, and left in heaps and piles or spread out as rolling prairie, to a depth of thirty to 100 or even 150 feet.

The continental moraine in North Dakota lies in such relation to the plateau that it suggests that something more than accident caused the moraine to lie just upon the edge of the plateau through a distance of 300 miles in North Dakota. The front or edge of the plateau, it has been stated before, extends across the state in a northwest-southeast direction. The moraine also extends across the state lying almost parallel to the edge of the plateau, and nowhere more than a few miles back from the slope which marks the edge of the plateau. Often in fact the coteaus or hills of the moraine are encountered immediately upon entering upon tne higher lands of the plateau top. The accompanying diagram (Plate IV) will assist in making clear the relations.

The direction of movement of the ice of the great ice sheet in this part of North America was probably very nearly at right angles to the front of the great plateau, so that the escarpment of the plateau served as a dam to hold back the ice in its onwara movement, and so the moraine occurs along the edge of the plateau because the ice could not advance beyond this position, a moraine always being formed at the edge of the ice sheet.

It is because of the occurrence of the moraine upon the edge of the plateau that so much confusion has arisen regarding the true nature of the coteaus. The term "coteaus" has been applied to the hills in this region. The altitude of the plateau above the prairie to the eastward has easily made this seem a part of "the hills," whereas the coteaus are hills on the top of the plateau and entirely different in their origin.

The Purpose of the Survey.—The extent of territory embraced by this great moraine within the state of North Dakota is probably



Idealized Cross-section of Missouri Plateau Southwest from Minot.

A Stony Ridge.

A Small Lake in Morainic District.

approximately 7,000 square miles. This region has until the last two or three years been mostly an undisturbed grazing range, native grasses adapted during the ages to the soil conditions of such a landscape growing in abundance, and eaten by the herds of cattle and horses which during the last thirty to forty years have succeeded the herds of buffalo and antelope that formerly roamed and grazed on these lands. The agricultural value of the lands was an unknown factor. The ranchman was the only settler. Little was known of the character of the lands, and little question was asked by homeseekers about these lands because there were other more desirable lands open to homestead entry.

Within the last two or three years, however, the demand for homestead lands has led to the settlement of some portions of these lands by farmers. The need for a scientific survey of the region and some determination of the character of the lands and their adaptability to farming or stock raising has therefore been more keenly felt. The region has long been regarded as adapted only to grazing, and no attempt at general farming has been made until very recently. The settlement of a farmer upon an occasional quarter section effectually overthrows the large ranching enterprises where cattle in great herds wander at will over a range unbounded by fences and limited only by the instinct of animals to stay about some central locality.

From a scientific standpoint a survey of the region was needed. The great continental moraine has been definitely mapped in all its vast extent from the Missouri river eastward to the Atlantic ocean, that portion only which lies north of the main line of the Northern Pacific railroad in North Dakota and thence on to the northwestern corner of the state remaining unmapped.

An Unique Part of North Dakota.—The region known as "the coteaus" is unlike any other part of North Dakota. There are other morainic lands in the state, but none that can vie with this region in rugged character, in abundance of the number of sloughs and lakes, and in the "everlasting monotony." It is not like the rugged hill-land west of the Missouri river, for there the hills nearly all have flat tops, and the land is nearly all cut up by streams and dissected by deep coulees. Streams are unknown among the coteaus, and the hills are all rounded in form and never flat on their tops.

This region is one that marks the halting-place of the great continental ice sheet in its passage across the northern portion of North America, and here was deposited the great mass of morainic material—rocks, sand, gravel, clay and soil; huge boulders so hard that they would phase the hardest stone-cutter's chisel and weighing many tons side by side with small rounded pebbles and sand grains, masses of clay and soil piled in heaps, hollows filled with water or grown up with reeds and rushes.

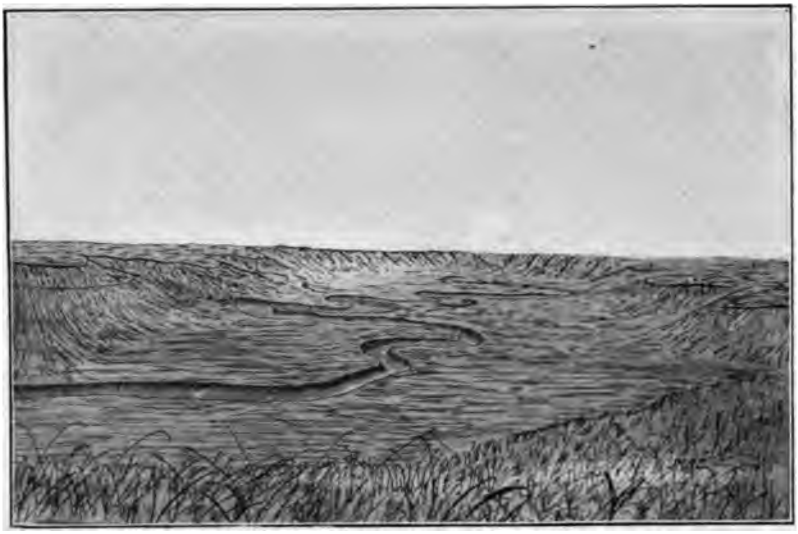
It is truly the region of hills—coteaus. They are the coteaus of the Missouri plateau because they are on the plateau. They are the highest and most rugged of morainic hills in the state because they were formed at the edge of the great ice sheet at a stage when the edge remained stationary, neither advancing nor melting back, for a longer time than at any other stage.

The Area Surveyed.—The portion of the great moraine lying south of the Northern Pacific railroad within the state of North Dakota has been mapped by Mr. J. E. Todd, of the South Dakota Geological Survey and the U. S. Geological Survey. The unmapped portion therefore extends from the Northern Pacific railroad between Steele and Bismarck north to the extreme northwest corner of the state.

Minot was made the railroad point of entrance to the field, and the first camp was established on section 22, township 152 north, range 84 west. From this point a careful study of the adjacent region was made, the plan being to extend the work both northwest and southeast till the limits of the state should be reached on the one hand and the area already surveyed and mapped by Todd on the other. The eastern side of range 83 was made the eastern limit of the area studied during the season of 1903, and during 1904 the work was extended over the territory westward to range 92, the territory included in the Fort Berthold Indian reservation not being included. The area mapped thus includes two tiers of townships in McLean county and extends to and includes the tier of townships crossed by the Great Northern railroad in Ward county.

DESCRIPTION OF THE AREA.

Three Types of Landscape.—The accompanying map shows fifty-eight townships. The area includes three types of landscape, viz., (a) a region which was passed over by the ice but which is not covered by moraines; (b) a region of strong morainic hills, lakes



Douglas Valley, South of Douglas Postoffice.

One of the Largest Hills in the Region.

and sloughs—the coteaus, and (c) a region outside the great moraine, west of the coteaus, a region over which the waters from the melting ice of the great glacier passed forming many broad and deep channels, and which may be called the region of overwash.

The first of these types of landscape is represented on the northeast portion of the map. This region is not included in the "hill country" of the coteaus, and is not a part of the region intended to be studied in this survey. It is shown on the map for purposes of comparison. This is rolling prairie, technically called ground moraine, and is adapted to general agricultural purposes. The line delimiting the ground moraine or rolling prairie from the morainic hilly land, the coteaus, crosses in a northwest-southeasterly direction the following townships: Township 152, range 83; township 153, ranges 83-84; township 154, ranges 84-85; township 155, ranges 85-86, and township 156, range 87.

This region is dissected by coulees. It has no lakes or sloughs of much importance. The coulees are deep, due to the fall or slope from the high plateau region toward the Mouse and Des Lacs valleys.

The second or morainic type of landscape, the real coteaus, includes the body of the area mapped. Here will be observed an utter absence of streams or coulees and many lakes and sloughs. The hilly portions of the map are indicated by the dotted shading.

The third type is that of the overwash region, represented on that portion of the map not shaded and marked by deep and broad valleys. This type is represented on the southwestern portion of the area mapped. It is a region over which the ice did not pass during the stage known as the Wisconsin, or the stage when the morainic hills known as the coteaus were formed, but over which passed vast floods of water, overwash from the melting of the great icesheet, and which has been eroded so that large channels have been formed, and extensive deposits of gravel have been left.

The Older and the Newer Drift.—In order to avoid possible confusion in the mind of the reader, who may question how the moraine, called the coteaus, can represent the edge of the ice sheet when drift materials are known to occur over a territory extending fifty miles west of the Missouri river, a word needs to be said regarding

the earlier and the later stages of the ice sheet in this portion of North America.

It may be assumed that the reader is familiar with the elementary facts of glacial geology, as the discussion of these facts here would involve more space than can be devoted to it.* However a brief statement of the facts regarding the older and the newer drift will be given here.

The moraine which is the principal subject of this paper, and which embraces the greater portion of the territory described in this survey, was formed at the edge of the ice during what is known as the Wisconsin stage of the great ice sheet. This moraine thus marks the limit of advance of the ice sheet during this epoch or stage of the glacial period.

It will thus be seen that the drift which lies west of the Missouri river does not belong to this stage or time; it is much older. An earlier invasion of ice from the north, the stage known as the Albertan, passed over this portion of North America long before the later invasion which formed the coteaus. A mantle of drift therefore covers the territory lying outside or west of the moraine formed during the Wisconsin stage and known as the coteaus. This drift in some places has been nearly all washed away so that but little or none at all remains covering the original land surface. It is often deeply eroded by the streams of ice water which flowed away from the great glacier of the Wisconsin stage. The valleys of Douglas creek, Shell creek and Little Knife river are examples of such channels that have been eroded into the older drift in their upper courses, and farther toward the Missouri river have cut entirely through the mantle of older drift into the underlying rock, as is shown by the outcropping ledges of sandstone, shale and lignite coal along the banks of these streams.

Further Description of the Area — The Eastern Slope.—The deep valleys of the Des Lacs and Mouse rivers cross the northeastern portion of the area included in the map. These valleys are broad and deep beyond all comparison with valleys made by rivers of such sizes as those now occupying these valleys. They are glacial

*To the reader who may be interested such a simple statement of the general geology of the state as is needful to an understanding of the present report, it may be suggested that a little book, "The Story of the Prairies," is a simple and popular description of the geology of North Dakota, and to this work the reader is respectfully referred. The book is published and for sale by the author, Daniel E. Willard, Fargo, N. D.

valleys, channels cut by the flood waters from the melting ice sheet. They have been eroded 300 feet into the plain which lies east of the great Missouri plateau. That their bottoms are below the lowest portions of the mantle of drift is shown by the occurence of sandstone ledges and lignite coal beds in their banks.

The plain which is crossed by these valleys is the characteristic rolling prairie of a large part of North Dakota. It is the rolling prairie for which the state is noted, and which makes North Dakota a "prairie state." This particular parcel of rolling prairie is a segment of the sloping front or edge of the great Missouri plateau. While the plain along the banks of the deep valleys of the Mouse and Des Lacs rivers is 300 feet above the bottom lands along the immediate stream beds, still the plateau top thirty miles west is more than 300 feet higher than this plain.

It is this slope from the edge of the plateau toward the deep valleys that gives the dissected character to the landscape. A rise of nearly 700 feet in a distance of forty miles in the railroad grade of the Great Northern railway from Minot westward has made possible the erosion of the deep and narrow V-shaped coulees which characterize the region.

Description of the Moraine.—The hilly region of the moraine in the area under consideration is from fifteen to twenty-five miles in width. This tract is made up of hills, ridges, rolling or even gently undulating prairie lakes, sloughs and hay meadows. A moraine is thus seen to be a somewhat complex thing.

The general aspect of the landscape after entering the morainic region is distinctly hilly. Many of the hills are high and their sides very steep and rugged. Often they are so closely set together that there is no space between the bases of the hills, but the bottom of one merges into its nearest neighbors. Occasionally a hill is so decked with stones large and small that the face of the hill appears like a vast stone heap.

Travel through the hills to one unaccustomed to the region is almost impossible, not only because of the roughness of the landscape and the frequent large rocks, but the hills all have such a resemblance that the inexperienced traveler easily mistakes the hill he thinks he is traveling toward, another insidiously substituting itself for the one he started to reach, while the traveler uncon-

sciously changes his course to go around a hill or avoid a slough. Where definite trails do not serve as a guide to the traveler he is almost helpless, and a journey is well nigh impossible.

The hills are sometimes so stony and steep that progress on horseback by one who is not accustomed to "the range" is almost impossible, a horse being liable to fall owing to the great number of rounded stones and the exceeding steepness of the slopes. Following a well worn trail one can often see his way but a few rods or even a few feet ahead, so crooked is the way as it winds and swings this way and that, among the hills. Leave the beaten past but a few steps and the unaccustomed traveler is as one adrift on the rolling sea.

One may be lost and pass within a few rods of a rachman's shack and not see it, for the shack may be and often is located in a hollow between the hills so that it cannot be seen often even from a short distance. The writer speaks from experience in seeking to find a ranch house while traveling a stranger and alone in this solitary region. A miss of a single dim fork in the trail caused him to pass by the last house in many miles, and as a result he lay down fatigued to the point of exhaustion upon the hard bosom of Mother Earth, and slept with the picket rope by which his saddle pony was held tied around his body till the cold of the small hours of the morning compelled him to travel on eagerly looking for the dawn which should enable him to find food—and what was more intensely needed, water.

A common custom is to place upon the highest points of the highest hills piles of rocks with often a pole supported in the midst of the rocks as a guide to the traveler. Such a landmark is always known to the inhabitants of the country, and if lost in fog or storm and one of these marks is seen it will indicate quite as accurately as section corners in the agricultural portions of the state where a ranch house is located.

One may pass a herd of hundreds of cattle within a few rods or even go through the herd where the animals are grazing in the hollows or on the slopes and perhaps be unaware of the herd's presence.

Tracts Less Hilly.—The whole of the morainic region is not of the extremely hilly type. Inter-morainic tracts embracing from a few acres to a hundred acres or sometimes more occur, and these

Looking Along a Stony Ridge.

Eroded Hill and Glacial Drainage Channel, Douglas Valley.

are sometimes fertile and adapted to cultivation. These intermorainic tracts are not, however, generally extensive enough or frequent enough to lend much importance to the region for general agricultural purposes. The hills are too stony and the soil too compact, dry and hard to render farming generally profitable or practicable.

All the region represented on the map by the shaded portion falls in the class of morainic lands and is not regarded as advantageous farming land. This does not mean that there are not some quarter sections that are desirable, and there are a few sections that might be untilized as farming lands. In time, as land becomes more valuable in agricultural districts, these lands which are now one great public domain will fall into private ownership, and the less hilly portions will probably be cultivated and the more hilly parts used for pasturage.

The region is a natural pasture land. The native grasses are very nutritious, and cattle and horses thrive during the whole year upon the forage, which cures as it stands, with only a little feeding in the winter. At present, and it seems likely for many years to come, that portion of this district which is included in the morainic tract will be more valuable for grazing and stockraising than for general farming. The settling of a few farmers in the hill country works serious injury to the stockraising industry, and really detracts from the development of the wealth of the state rather than adding to it, since the plowing and raising of cereal crops on a few small patches prevents the free range of stock over the hill country surrounding, and thus causes a vastly greater area to lie desert.

A further feature that adds to the value of these lands for exclusively grazing purposes is the great number of "dry" lakes or sloughs, which are often real lakes during the season of heavy rains or melting snows, the hay meadows. These small lakes and sloughs are a characteristic feature of the morainic territory. There are sometimes so many of these that travel during the season when they contain water or when they are too wet to be crossed is almost impossible. There are sometimes as many as fifty to 100 of these small hay meadows, lakes or sloughs, on a single section, though perhaps twenty-five to forty on a section would be about an average.

These furnish forage during seasons when the hillsides do not produce enough grass for the herds, and hay in almost unlimited

quantities is cut in them and stacked for winter feeding. If this great coteau region could be used exclusively for grazing without interference from attempted farming on the few small areas on which farming is at all practicable, and could be used to its full capacity, a vast source of wealth to the state would result. This is not saying that the present wholesale range and wasteful methods in vogue on the ranches would accomplish this end, but if the low and more level tracts such as are capable of profitable plowing could be used by stockraising farmers for the growth of alfalfa, corn and other coarse forage crops for winter feeding, and all the hay which grows in the sloughs could be untilized, so that enough herds could be wintered to eat all the grass which grows on the inaccessible hillsides and rough lands, a livestock interest vastly greater than that which the region has heretofore sustained would be possible.

The Extra-Morainic Territory.—There remains to be described the territory lying west of the morainic tract between this tract and the Missouri river. This has been referred to as the overwash region adjoining the moraine.

It has been pointed out before that the region is mantled with the older Albertan drift, and that it has been furrowed and eroded into deep channels by the pasage of the waters of the melting ice sheet southward and westward into the Missouri river.

It will be seen by reference to the map (Plate III) that the eastern edge of the moraine is quite definite and simple, whereas the western side is very irregular, the moraine being indented by deep sinuses and inverted loops. This is the usual thing that the outside of a moraine is ragged and uneven while the inside or that toward the ice sheet is comparatively even. This will be readily understood when it is borne in mind that the great moving ice mass pressed upon the east and north side of the moraine while at the same time the materials of which the hills of the moraine are composed were being deposited by the ice and the edge of the melting ice sheet was jagged and uneven, due to unequal melting. Long lobes pushed out from the front of the ice also, and thus the outer edge of the great deposit from the ice, which is known as a moraine, is very irregular and uneven.

One of the most conspicuous of these embayments in the moraine with its corresponding lobe of hills has been called the Douglas valley, from the name of the small creek that now occupies the old

A Landmark.

The Home of an Early Settler.

Road Ditch Eroded in Four Years. Ditch Discharging Into Red River of the North.
Township 140, Range 48.

channel below Douglas postoffice. This "valley" includes portions of townships 149-152, ranges 84-85.

The upper portion of this valley is beautifully set with lakes, in fact the Rice lake and Bartron's lake are among the most beautiful and clear in the state, having fine gravelly shores and bottoms. The surface is far from level in the portion of this valley above Douglas; on the other hand it is quite distinctly rolling or even hilly, and the soil is compact and stony, much like that of the moraine over much of it. The valley is not a valley at all as that term is ordinarily used. It is rather an overwash plain from the great ice sheet. The tract of gravelly and sandy soil in the northern portion of the valley is probably thus explained.

South from Bartron's lake and Douglas postoffice the valley-like character becomes more conspicuous. The surface is more nearly level, and the soil is sandy and gravelly, assorted and washed by the glacial flood waters.

Extensive plains of gravelly and sandy soil lie along the border of the moraine, typical examples of overwash from the ice sheet. Frequently such plains can be distinguished from a distance by observing the characteristic growth of weeds and grasses which thrive upon such soil.

A BRIEF HISTORY OF GLACIAL LAKE AGASSIZ.

A POSTHUMOUS PAPER BY CHARLES M. HALL.

TOPOGRAPHY.

The area considered in this paper lies within the region known as the Red River valley, which, during the closing stages of the glacial period was filed with water and known as Glacial Lake Agassiz. This region has been described by Mr. Warren Upham in U. S. Geological Survey Monograph XXV.

The topography is exceedingly simple. Two-thirds of this area lies as one vast level plain. Standing near the middle of the valley, if we may call it a valley, one looks across this vast expanse as far as the eye can reach, with his vision interrupted only by the groves planted by the early settlers, and marking the location of these older farm buildings, and the trees which border the winding courses of the streams. One is reminded of the level of the mighty

ocean, indeed in many places one's vision is bounded apparently in all directions by the tops of buildings and trees in the far distance like the masts of a ship disappearing at sea, no physiographic feature being great enough to be detected by the eye from the level. This feature is explained in the U. S. G. S. Topographic Atlas entitled "Physiographic Types," where the Fargo quadrangle is used to represent a region in youth. The general altitude of the level plain is about 900 feet above sea level. On either side of the Red River of the North which flows from south to north across the area the land rises with a gentle slope of from 1 to 4 feet per mile. Approaching the western bottom of the old lake bottom the surface is marked by a more sudden rise and broken by a series of ridges running north and south which mark the beaches of the old lake at its different stages. In the northern part of the area there is a rise of 200 feet in a distance of about 5 miles to the upper or highest level of the old lake. Beyond this the rolling prairie merges into the low morainic hills just west of this distrct, the highest part of the area now being considered being crossed in the northwest corner by the 1,200 foot contour.

In the southern half of the area, or south from the point where the Maple River debouches upon the old lake bottom, the margin of the lake bottom is marked by a more sudden rise of about 60 or 70 feet within two or three miles onto a sand plain almost as nearly level as the lake bottom itself. This plain extends from a little north of the Maple River beyond the limits of the area to the south. It is broken by the Maple and Sheyenne valleys. The Sheyenne River has eroded a gorge from 100 to 140 feet deep across the plain. On either side of this valley the plain is broken by a series of hills or dunes ranging from mere undulations in the surface to huge mounds 130 feet high.

GEOLOGIC HISTORY.

Just previous to the closing stages of the last great period of the earth's history preceding the present, when the northern part of North America was covered with the great ice sheet, not unlike Greenland today, Minnesota and North Dakota, as far west as the Missouri River, were deeply buried beneath the great mountain of moving ice. In the region under discussion, a portion of the great Minnesota ice lobe had already found an old drainage basin far be-

neath where the valley of the Red River of the North now lies, and had for centuries been leveling its rugged surface by the powerful action of its slow movements and adding the debris to that already gathered farther north and east and depositing it at its border, forming the great hills of the terminal moraines of the Coteau des Prairies and the Coteau du Missouri.

The close of this important period was marked by a change in the elevation of the land, a change of climate and a gradual melting of the ice back to points farther north; this is known as the retreat of the ice sheet. This was not a sudden or even a continuous melting or recession, but was marked by a succession of pauses. At each pause sufficient time elapsed to accumulate enough debris along the margins so that when another retreat began a row of hills called a terminal moraine marked the line of the last pause. None of these pauses allowed the accumulation of nearly the amount of material that was deposited at the earliest margin.

Seven moraines were accumulated and left by the retreat of the ice sheet before the epoch is reached which determined the surface geology of the Red river valley and the region under discussion. The seventh moraine, known as the Dovre, marked the edge of the ice sheet when its border lay along the line of hills which lies near White Rock, South Dakota, thence extending north and west near Lidgerwood, Lisbon and Milnor, and following in general the course of the Sheyenne River to Devils Lake.

As the ice melted back from the position just described, the water from the melting ice began to fill the basin of the pre-glacial Red River valley. The continued melting of the ice caused the basin to overflow and an outlet, naturally, was formed at the lowest point of the rim. This outlet channel thus formed was that in which Lakes Traverse and Big Stone now lie, and which was the former channel of the Sheyenne River before the last recession of the ice sheet. The great lake which thus began, increased in size as the ice front melted back, until it covered an area nearly as great as that of all of our Great Lakes combined. This lake is called Glacial Lake Agassiz, for a detailed description of which see U. S. Geological Survey Monograph XXV, by Warren Upham.

The action of the wind and waves along the border of the ancient lake formed beach lines like those formed by great lakes today, accumulating sand and gravel in places into great ridges. The cut-

ting down of the outlet and the tilting of the land during this period gave rise to the formation of several well-marked beach lines running nearly parallel. These in the upper part of the lake were five in number, called the Herman, Norcross, Tintah, Campbell and McCauleyville, from towns having these names in western Minnesota located on these respective beaches. Following the formation of these beaches the lake found an outlet to the north as a result of the recession of the ice sheet, and many other beaches were formed, until, on the final disappearance of the ice the Red River valley was left approximately as it is today. The water was very deep in the middle of the lake during its highest stage, being 250 feet where the city of Fargo now stands. Great ice bergs could thus float down from the north and would strand where they were driven by the prevailing winds after dropping their burden of boulders, many of which have been found along the east side of the valley. The streams flowing into the lake, made vastly larger than any streams in the region today by the floods of water from the melting ice, brought a great deal of sediment into the lake. Where these streams entered the lake, great deltas were often formed like that of the Sheyenne. Here the sandy constituents of the sediment were dropped near the mouth of the stream, the finer materials being carried out to the middle of the lake. In this way the level bottom was built up to a thickness of 60 to 70 feet of deposit.

Thus the history of the lake has been the history of the region under consideration.

THE RIVERS AND DRAINAGE OF SOUTHEASTERN NORTH DAKOTA.

A Posthumous Paper by Charles M. Hall

The entire area is drained by the Red River of the North and its tributaries, the Buffalo in the east and the Wild Rice and Sheyenne in the west. The Red River of the North represents approximately the axis of the Red River valley. It enters the area from the south at an altitude of 900 feet above tide, taking a tortuous course a little west of north. It leaves the area at the north at

860 feet, representing a fall of forty feet in less than 40 miles. The river in its winding course represents no less than eighty miles, which gives to the river a fall of not over six inches to the mile. The channel is from 200 to 300 feet broad and from twenty to sixty feet deep, and from its meandering nature, usually has one very steep bank and one more gently sloping one. The immediate river banks are usually slightly elevated by river silt often forming a gentle slope for a short distance away from the river bank. The channel of the main stream is sufficient in ordinary seasons to carry off the drainage of the land, the usual capacity of the stream at Fargo being not far from 25,000 cubic feet per second. However, following seasons of heavy snow fall, when the melting of the snow is hastened by rainfall, the present channel is entirely inadequate to the task and the river has been known to overflow its banks and cover the surrounding country, reaching in places a width of fifteen miles. These floods have been known to occur within recent time in 1897, 1893, 1882 and 1881. These floods occur at the melting of the spring snows in April, when the river reaches its high water marks. At times heavy June or July rains will cause a rise in the river, but usually the mid-summer floods cause no serious damage. The spacing of the tributaries of the Red River of the North seems to have been determined by the streams of water entering the valley as the water of the lake receded. All of the perennial streams tributary to the Red River of the North have their sources outside the area of the ancient Lake Agassiz, and usually show every evidence of once having been much larger streams than at present. These tributaries are in truth almost devoid of sub-tributaries, usually receiving the drainage within the old lake bottom from the land only for a short distance on either side of the stream. This gives rise to broad areas between these rivers which have little or no definite drainage. Thus the three perennial streams, the Sheyenne, Wild Rice and Buffalo, have been lowered full-fledged streams into their present places by the recession of the lake. The spaces between these rivers, as has been suggested before, have little or no definite surface drainage. That which has developed is in the form af coulees which extend back from one to five or six miles from the main stream. These carry water only following heavy rains or from melting snows, remaining dry the rest of the year. These are from

twenty to forty feet deep near the river, but rarely extend back from the river more than a mile or two. At first it seems strange that so young a drainage system should still exist, but this is accounted for by the extreme youth of the region.

The lacustrige deposits, when once started, erode rapidly. In 1895 a wagon road was graded east of the river between sections 30 and 31, Oakport township, (T. 140, R. 48), for a distance of about six miles. The farmers at once began to drain their fields into the ditch made at the roadside. Erosion immediately became active for the full distance of six miles from the river, deepening and broadening the roadside ditch. In a period of four years the water had eroded a channel eighty feet wide and twenty-five feet deep for nearly a mile from the river destroying the road and necessitating the building of substantial bridges.

The Wild Rice and Sheyenne Rivers have their sources outside the Red River valley, and from the places where they enter the level plain of the valley bottom, their channels and meandering courses are not unlike that of the main stream.

The Wild Rice river has its source among the morainic hills near the southern boundary of the state of North Dakota. It enters the valley in eastern Sargent county, crossing the Sheyenne Delta for a distance of twenty-four miles in a direct line. It receives little or no lateral surface drainage in this region. It flows north parallel with the main stream more than forty miles before entering it. In the spring the river is full, but after the June and July rains it often becomes completely dry. The fall rains start the flow again, but the stream freezes to the bottom in many places in the winter.

The Sheyenne is the most interesting stream of the region. Having its source southwest of Devils Lake it flows 180 miles before entering the valley of the Red River of the North. It occupies a valley ranging from one-fourth of a mile to one mile in width and from 75 to 150 feet deep. During the principal period of the existence of Glacial Lake Agassiz the chief source of water besides that coming directly from the ice front came through the Sheyenne River.

This glacial river entered the lake about ten miles southeast of Lisbon, in Ransom county. The amount of sediment brought into the lake was very great and the deposit thus formed is known as the Sheyenne Delta. Upham estimates the area of this delta at 800

Bed of Wild Rice River in Red River Valley, Southeast of Abercrombie.

Bridge Over Sheyenne River at Haggart Station.

square miles, with an average depth of forty feet and volume of six cubic miles. (U. S. G. S. Monograph XXV.)

The position of the Sheyenne Delta is shown on the accompanying maps. The finer clay sediment was carried far out into the lake, leaving the coarser sandy material to form the delta. As the lake receded the vast delta of fine sand was left bare, and the river began to excavate a channel across its own delta. The water which entered the lake during its highest stages and which brought most of the sediment which formed the sediment, was greatly diminished by the diverting of the waters from the melting ice from the sources of the Sheyenne into other channels before the lowering of the lake had reached the fifth stage, or that of the formation of the McCauleyville beach, which shore line marks approximately the outer border of the delta, and before the river had cut a channel across its delta. Had this not been so the delta must have extended further into the valley locally where the valley of the Sheyenne debouches upon the Red River valley in northeast Barrie township.

After entering the valley of the Red River of the North the river takes a serpentine course northeast nearly forty miles before finally entering the Red River of the North. Although the Sheyenne River has a drainage area of over 4,000 square miles above its junction with the Maple yet the stream does not suffer from floods nor seriously endanger the lands along its lower course, for the channel below where it enters the Red River valley lowlands is capable of caring for the water as fast as it descends from the tortuous channel of the upper stream.

During the higher stages of the lake, while it yet had an outlet toward the south, the waters of the Sheyenne, as these entered the lake, drifted southward distributing sediment along the margin of the lake and finding an outlet into the Minnesota River. However, to divert the present Sheyenne River and to make it discharge its water into Big Stone Lake and the Minnesota River, as it once did, and as has been advocated as a measure to prevent floods in the Red River valley, is entirely impracticable as the old channel is 150 feet above the present stream.

As the Sheyenne entered the Red River valley during and immediately following the McCauleyville stage of the lake it doubtless took a course almost directly east. Evidences of this old course are still marked first by the sharp bend of the stream to the east as it

enters the valley in the southeast corner of section 11, Barrie Township, and second, following the course of the river after it turns to the north the old channel is again marked on sections 8, 9, 10 and 14, Walcott Township. The volume of water could not have been great, else the first channel had kept open. The extreme level character of the land made it easy for the waters to be diverted northward, whence it flows more than thirty miles almost parallel with the Red River of the North.

Along the Sheyenne valley occur a number of springs which usually keep it flowing during the summer months, however, it has been known to become completely dry. It is noticeable that the stream has almost no tributaries, and where the valley crosses the sandy plain of its delta it is rare that any surface drainage for more than a mile from the stream ever gets into the river. It is believed that were it not for the great channel, eroded by the glacial waters, the greater part of the 4,000 square miles of its drainage area would be like the Devils Lake region and a large area between the Sheyenne and James Rivers, an area of undeveloped drainage.

The Maple River has its origin and course developed in much the same manner as the Sheyenne. The drainage area is much less, its valley not so deep. Like the Sheyenne and other tributaries of the Red River of the North it turns northward after entering the valley. It unites with the Sheyenne ten miles above where their combined waters enter the Red River of the North. During dry years the bed is usually almost or entirely without water.

In connection with the Maple River is a peculiar topographic feature. Beginning at the east side of section 19, Maple River Township, Cass county, is a serpentine ridge from fifteen to twenty-five feet high, following in general the course of the Maple River. It is plainly traced for a distance of twenty miles. It can hardly be in any way connected with a beach line of the retreating lake, for the ridge originates with its crest 945 feet above tide and seems to be independent of the general topography, the lower part of the crest being not over 910 feet above tide. Across Maple River township the ridge contains much sand, and several sand and gravel pits have been opened. There is in each case less than five feet of sand and gravel. As the ridge is traced farther north across Durbin, Harmony and Raymond townships, it offers attractive sites for farm buildings, but in nearly every case in drilling or boring for water,

Island Park, Fargo, Showing Flood of 1897.

Red River of the North at Pembina, Showing Ferry.

quicksand is struck from twelve to eighteen feet below surface, which is rarely penetrated far. The ridge follows closely the general course of the Maple River. It contains coarse materials near its origin and quicksand along the balance of its course. It is independent of the natural topography. Its origin is near where the Maple River makes its debouchure into the level valley bottom. All this leads to the belief that it was formed by the Maple River entering comparatively shallow water, dropping its coarser materials first and the fine quicksand in the more gently moving current farther out from shore. It acts in every respect like what would be called an esker or osar in glaciology, but what could confine a stream of water in a shallow lake in one course long enough to deposit such a prominent ridge is not clear.

SOIL SURVEY OF THE GRANK FORKS AREA, NORTH DAKOTA.

By Charles A. Jensen and N. P. Neill.

(Reprint from Field Operations, Bureau of Soils, 1902.)

LOCATION AND BOUNDARIES OF THE AREA.

The area surveyed is situated in Grand Forks county, one of the eastern tier of counties of North Dakota, lying a little north of the east and west medial line. The eastern limit of the area is the Red River of the North, which also forms the state boundary line. Grand Forks, in the northeastern part of the area, is situated in about north latitude forty-seven degrees, fifty-five minutes and west longitude ninety-seven degrees, five minutes. The area extends a distance of thirty-four miles west from that town. For the first fifteen miles the area is six miles wide, and for the remaining eighteen miles it has a width of twelve miles. The area includes township 151 north, ranges 50 to 55 west, inclusive, and township 150 north, ranges 53 to 55 west, inclusive, and covers an area of 314 square miles or 200,960 acres. Probably most or all of the types of soil in the county occur in the area mapped.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The Dakotas were originally a part of Michigan, Wisconsin, Iowa and Minnesota, and during the years between 1834 and 1858 the

boundaries were often changed. Civil government of the Dakotas did not begin until 1861, and North and South Dakota were not constituted separate states until 1889.

British and American fur companies were the first to occupy Dakota territory, and land was not taken up for agricultural purposes until 1851, when a few white settlers obtained a few hundred acres from the Sioux Indians. Agricultural pursuits were, however, often interrupted, even at this late date, by the Indians, who a number of times drove the settlers out of the country.

Grand Forks county was created June 4, 1873, from part of Pembina county. Its boundaries were changed in 1875, in 1881, and again in 1883. The first settlement in the county was Grand Forks, the county seat, which was established late in the seventies. What was but an aggregation of a few houses in 1879 is now a thriving town of 8,000 or 9,000 inhabitants. Agricultural development at that time was limited to a few isolated ranches, as there were no railroad accommodations so far north until 1880-81, when the Great Northern railway was built through Grand Forks westward. Agricultural development was very rapid along the main line of this road and branches were soon built which gave greatly increased shipping facilities and resulted in a great impetus to farming in various parts of the county and state.

The increase in improved farm lands has, however, been greatest during the last decade, within which time the number of farms and the value of improvements have almost doubled. Much of the western part of the county is not yet improved or developed, being somewhat hilly and less desirable generally than the eastern part.

CLIMATE.

The climate of the Red River valley may be classed as subhumid. The annual rainfall, which is approximately twenty inches, is usually so distributed as to furnish enough moisture for crop purposes during the growing season. Occasionally, however, a season of drought occurs when crops are practically a failure. The year 1902 was very favorable as regards moisture, but the spring season was late and in a few instances cereals could not be planted in time to mature. The summer months are warm without being uncomfortable, and the fall months cool—conditions required for the proper maturing of the hard variety of wheat grown.

Hailstorms sometimes do considerable damage, and a few of these occurred in various parts of the state in 1902. A small section of the county sustained damage in July by a hailstorm, the force of the wind being sufficient to upset a few houses and telegraph poles.

The wind movement is comparatively high, especially during the fall of the year. It is sometimes strong enough during the summer months to badly damage heavy grain, especially if the wind is accompanied by rain, as sometimes happens.

The following table shows the normal monthly and annual temperature and precipitation, taken from the weather bureau records:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Larimore		University	
	Temperature—degrees F.	Precipitation—Inches	Temperature—degrees F.	Precipitation—inches
January	4 0	0.91	4.0	0.55
February	5.0	.31	6.0	.51
March	17.0	.55	19.0	.62
April	41.0	1.47	41.0	2.88
May	53.0	2.54	54.0	3.14
June	60.0	3.68	63.0	4.32
July	66.0	3.35	67.0	1.96
August	64.0	1.97	....	1.94
September	56.0	.61	56 0	1.12
October	42.0	.79	42.0	.76
November	22.0	.36	22.0	.76
December	18.0	.75	10.0	.62
Year	38.0	17.25	....	19.64

PHYSIOGRAPHY AND GEOLOGY.

The topography of the area is very simple. The level alluvial area extends from Grand Forks west to within about two miles of Emerado. The slope of this area is less than one foot to the mile. From there westward to the glacial drift there are eight or ten beaches or ridges with a northwest and southeast trend, varying in height from a few feet to perhaps forty or fifty feet, though the latter height is seldom attained in the area surveyed. These ridges are from one-half mile to two or three miles apart and have very gentle slopes. Often shallow swales extend from one beach to another. Sometimes the beaches form plateaus.

From the Herman beach westward as far as the area surveyed extends there is a rise of perhaps 100 to 200 feet. This is the glacial drift area and consists almost entirely of small hills and hollows

or swales scattered about indiscriminately. The individual hills are not extensive in area and vary from ten feet to sixty or seventy feet in height, with slopes generally not too steep for cultivation.

There are many glacial bowlders scattered about these hills and in the whole of the western part of the area surveyed. These occur in small masses or singly, and some of them are of enormous size. They are, however, not numerous enough to interfere seriously with cultivation.

There are a number of stream courses, a few deep but most of them shallow, traversing the area in a generally easterly direction. With few exceptions these are dry during the greater part of the year.

The area surveyed includes a part of the bed of glacial Lake Agassiz, and extends from Red River (approximately the middle of the valley), to and slightly beyond the upper or western beach of the lake into the glacial drift. The area thus traverses the lacustrine deposits in the middle of the valley, the bench lands and beaches westward, and the upper beach of the lake. The extreme western limit of the area extends several miles into the glacial drift, which corresponds to Fargo gravelly loam. The altitude of Grand Forks is 830 feet above sea level.

The upper beach, several miles west of Larimore, known as the Herman beach, marks the western limit of the lake, while from there to several miles east of Emerado is a series of smaller beaches, representing various temporary stages of the lake during its recession. There are smaller unimportant beaches between Ojata and Grand Forks. These beaches consist of sandy loam, sand and gravel, and reworked till, the surface soil being invariably sandy loam, generally gravelly. Some portions of these beaches, especially those near the western limit of the lake, closely resemble eskers. These beaches were undoubtedly formed by the action of the surf of the lake while its waters remained at one level for longer or shorter periods, in the same manner that beaches are formed at present along the shores of existing bays and lakes. The formation of the beaches was also assisted by the debris continually being unloaded by the floating ice. The coarser material would thus be washed up along these beaches and the finer particles, with occasional pebbles, would settle in the swales between them.

Small kettle holes are quite numerous in the western part of the area and more rarely in the eastern.

The alluvial clay proper, or as classified during the survey, Miami black clay loam, does not appear along the main line of the Great Northern railway until a point about two miles west of Ojata is reached, while west of this the surface soil is sandy loam with a clay or clay loam subsoil. The alluvial silty loam, grading into clay or clay loam at a few feet below the surface, varies consideraby in depth and at Grand Forks is probably from fifty to seventy-five feet deep. This stratified alluvial deposit is underlain by glacial till or drift, which gradually approaches the surface westward, forming the subsoil of Fargo gravelly loam and finally outcropping a few miles west of Larimore as a beach. At Fargo the drift has a thickness of 150 feet. Under this drift is found cretaceous shale, probably the Niobrara and Fort Benton. It has a thickness at Grand Forks of over 300 feet. This is in turn underlain, at a depth of 385 feet at Grand Forks, by granite and gneiss which extends to an unknown depth.

Over a large part of the area, especially in the west, large bowlders of granite, gneiss, and more rarely limestone are found in local masses, having been dropped by the floating ice. A large number of local beds of crystalline gypsum were found at a depth of from one to six feet below the surface. Apparently similar beds were also found in the glacial drift.

As gypsum beds are found almost invariably in the slight local rises or ridges in the alluvial soils, and as the texture of the soil in those places is lighter than the surrounding soils, it would appear that these beds are due to gypsum and accompanying salts being dropped there by the floating ice. Against this theory may be urged the fact that bowlders are not found in or around these local rises. Bowlders of fair size are, however, found at a considerable distance east of Ojata, and as gypsum has a lighter specific gravity than granite or limestone, there would at least be a chance of its being carried farther by the smaller floating ice masses. Moreover, the lake must have been comparatively shallow at the time these gypsum beds were laid down, for over some of them there is less than a foot of soil. With the lake at a low stage it would be impossible for large ice masses carrying great bowlders to drift so far eastward.

SOILS.

Five types of soil were recognized in the area surveyed: Fargo gravelly loam, Miami sandy loam, Fargo loam, Miami loam and Miami black clay loam. Besides these types a number of small areas of muck were mapped.

The texture of the surface soils in the eastern part of the areas is as a rule heavier than in the western, the difference being due to the difference in origin. Those in the eastern part of the area are of direct alluvial origin and are loams or clay loams, while those in the western part have been more or less modified by the action of the shore water of the ancient lake and by drift and are consequently lighter in texture.

AREAS OF DIFFERENT SOILS

Soil	Acres	Per cent	Soil	Acres	Per cent
Miami sandy loam	68,800	34.3	Fargo loam	12,352	6.1
Fargo gravelly loam	51,136	25.4	Muck	6,592	3.3
Miami black clay loam	44,352	22.1			
Miami loam	17,728	8.8	Total	200,960	

FARGO GRAVELLY LOAM.

The Fargo gravelly loam, occupying, as typically developed, the extreme western limit of the area, consists of from one to two and a half feet of loose black sandy loam with small gravel disseminated through it varying in size from very small particles to pebbles about one-half inch in diameter. The surface is also generally gravelly, though over large areas this feature is absent. The surface soil is underlain to a depth of about three feet by a black or gray gritty loam, which is in turn underlain by gritty, stiff white or yellow, or mottled gray and yellow loam, containing small gravel and frequently small concretions of iron oxide. This material often grades into clay loam or clay at a depth of five or six feet. Local beds of crystalline gypsum are often found at a depth of two or three feet. Over the surface are scattered local masses of glacial bowlders of granite, gneiss, schists and limestone, but these are not numerous enough to seriously interfere with cultivation.

The topography is undulating, consisting of small irregular hills or knolls of small surface area varying in height from about ten feet to forty or fifty feet. Between these are shallow depressions in the shape of swales or kettle holes. The slopes of these hills are

not steep and with very few exceptions are easily cultivated. The soil on their summits is lighter in texture than that of the intervening hollows and contains considerable gravel, while the surface soil in the depressions is often very mucky, though not sufficiently pronounced to be classed as muck.

This type is well drained, with the drainage eastward, and many shallow and a few deep creek depressions traverse it, the majority of which, however, are dry during the greater part of the year.

A few local alkali spots were found in this soil, but none of great enough extent to show on a map of the scale used. The clay and clay loam subsoil generally carry some and often considerable alkali, but this does not lie near enough to the surface to interfere with plant growth. The subsoil often carries a very large amount of lime and when mixed for tests in alkali determinations it gives off a strong mortarlike odor. The lime is probably due to limestone which has been crushed and ground by the ice, as small gravel of this rock of all sizes is scattered through the soil.

The Fargo gravelly loam is largely composed of glacial till or drift, though in the eastern limit of the type the material has been reworked by the wave action of the ancient lake. The soil there gives evidence of having been considerably washed, and hence there is much more gravel and the interstitial soil is lighter than in the area farther west.

This soil is generally adapted to wheat, oats and barley, and during seasons of favorable rainfall good yields of these crops and of flax can be produced. The soil on the higher elevations does not, however, retain moisture well and is apt to be affected by drought.

Much of this type is still unbroken and unimproved and such areas bear a splendid growth of prairie grass and would be excellent for grazing range stock.

A valley phase of the Fargo gravelly loam consists of from one to six inches of black, sometimes mucky, sandy loam, often containing small gravel, underlain to a depth of two feet by a gritty black or gray loam containing small pebbles up to one-half inch or so in diameter. This is in turn underlain to a depth of six feet by a gritty, stiff, mottled gray and yellow clay loam or clay, interspersed with small gravel and usually with small concretions of iron oxide. Sometimes the sixth foot, especially in the eastern part of the area, becomes a silty loam of the same material as the subsoil

of the Miami black clay loam. Beds of crystalline gypsum are often found in this phase at any depth below the first foot. The surface, especially in the former estuaries of the old glacial lake, is often strewn with glacial bowlders of granite, gneiss, limestone and schist.

This phase is found in the western and middle parts of the area surveyed. It occupies swales between the beaches and the estuaries of the ancient lake. The latter position is principally found south and southeast of Ojata, where the soil sometimes is intersected by small beaches and ridges.

The areas of this phase of the soil are usually level, though, as before stated, they are often found in low places. Although standing water is on an average only from four to six feet below the surface, they were not swampy at the time the survey was made. A few of the natural swamps, especially southeast of Ojata, are of this soil type.

The condition of this soil could be considerably improved by artificial underdrainage, using the sloughs which frequently dissect the areas for the main drains or outlets.

There is but little alkali in the first three feet of soil in the area west of Larimore, but there is usually considerable in the subsoil. On the other hand the area in and around Ojata is badly impregnated with alkali, both in the surface soil and in the subsoil. This subject will be considered in the chapter on "Alkali in Soils."

The area west of Larimore is well adapted to wheat, oats, barley, flax and corn, but the area in and around Ojata is better adapted to hay and pasturage under present conditions, as there is generally too much alkali in the surface soil for profitable cultivation of the cereals, which make but an indifferent growth. A good crop of wild prairie grasses, including salt grass, was growing on this soil at the time the survey was made. Indeed, over the greater part of the area about Ojata it would be nearly impossible to say whether or not the soil was alkaline without making the chemical test. Grass knee-high was seen on soil containing over one per cent of alkali in the first three feet, with a uniform distribution.

The table on the following page shows the mechanical composition of the Fargo gravelly loam.

MECHANICAL ANALYSES OF FARGO GRAVELLY LOAM

[FINE EARTH]

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7445	SE. corner sec. 9, T. 150 N., R. 55 W	Sandy loam, 0 to 12 inches.................	7.30	1.48	4.64	5.62	13.76	8.30	42.60	22.96
7449	SW. corner sec. 15, T. 151 N., R. 55 W......	Gravelly sandy loam, 0 to 12 inches.........	4.87	2.30	6.42	7.84	29.80	11.30	26.22	15.16
7447	E. corner sec. 21, T. 151 N., R. 52 W..........	Loam, 0 to 12 inches...	3.92	1.72	4.34	3.76	9.94	15.10	46.86	18.20
7448	Subsoil of 7447	Gravelly clay loam, 24 to 36 inches..............	.34	2.28	4.36	4.00	10.62	10.40	47.20	20.78
7451	Subsoil of 7449	Gritty loam, 48 to 60 inches.................	1.02	2.94	7.64	6.24	15.86	12.36	32.80	21.16
7450	Subsoil of 7449	Gritty loam, 24 to 36 inches.................	2.80	3.74	6.34	5.92	21.06	9.94	26.62	26.26
7446	Subsoil of 7445	Gritty loam, 24 to 36 inches.................	1.57	3.26	6.74	5.42	13.68	9.20	35.10	26.26

MIAMI SANDY LOAM.

The Miami sandy loam consists of from one to two feet of loose black sandy loam underlain to a depth of three feet by a gray sandy loam. This is in turn underlain by mottled gray and yellow sandy loam to a depth of six feet. Sometimes the sixth foot is yellow sand containing small concretions of iron oxide. Rarely the second foot grades into loam, but in this case the sandy loam is found beneath it. In the southeast quarter of township 150 N., range 53 W., the soil has a fine silty sandy loam subsoil that extends from a depth of three feet to one of six feet.

This soil type is found on the higher-lying areas in the western and middle parts of the area, excepting the glacial-drift area, the typical soil being found in and around Larimore. The beaches, which generally consist of the same material as the surface, contain considerable gravel at a depth of two or three feet, and this coarser material often outcrops on top of the beaches. Some parts of these beaches, especially near the western limit of the area, closely resemble eskers. The large glacial bowlders commonly found on the other types are usually absent from this one. The soil owes its origin mostly to wave action during the existence of the glacial lake.

The Miami sandy loam is well drained and free from alkali and is generally well adapted to wheat, oats, flax and barley. Owing, however, to the light and loose texture of the surface soil, of some of the areas a plentiful supply of rain is necessary to insure good crops. The beaches are generally too light and loose in texture and often too gravelly to be of any value for agriculture.

This is the only type in which gypsum beds were not found at some depth or other.

Below are given the mechanical analyses of this soil:

MECHANICAL ANALYSES OF MIAMI SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.05 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7452	W. center sec. 23, T. 151 N., R. 54 W..........	Sandy loam, 0 to 12 inches................	2.79	0.76	3.86	6.88	56.32	6.38	18.94	5.90
7455	Center NW. ¼ sec. 24, T. 151 N., R. 55 W...	Sandy loam, 0 to 12 inches................	3.59	.10	1.32	3.32	50.76	14.22	18.30	11.10
7453	Subsoil of 7452..........	Sandy loam, 24 to 36 inches.......	1.22	.64	3.90	7.60	68.94	5.58	5.52	7.02
7454	Subsoil of 7452..........	Sandy loam, 48 to 60 inches................	.72	2.46	9.20	8.24	55.70	6.34	8.60	9.12
7456	Subsoil of 7455..........	Heavy sandy loam, 24 to 36 inches..........	.86	.24	.88	3.12	43.56	14.32	14.54	22.60

FARGO LOAM.

The Fargo loam consists of about six inches of black sandy loam of the same character as the surface soil of the Miami sandy loam, underlain with black loam or light clay loam to a depth of one and half feet. Beneath this, to a depth of two feet nine inches, is a fine gray, sometimes silty, loam containing no appreciable amount of grit and very much like the corresponding section of the Miami black clay loam. This stratum is in turn underlain to a depth of six feet with a fine sandy, usually silty, loam, which is generally mottled, contains small concretions of iron oxide, and is of a gray and yellow color below the fourth foot.

Small beds of gypsum often occur in the second foot, but owing no doubt to the light subsoil there is usually no excess of alkali in the first three feet.

The drainage of this soil is usually good, and the type is almost an ideal one for an alkali district, as the light subsoil allows the alkali to be carried away by the underground water, while the surface soil is heavy enough to retain moisture well.

This soil occupies the slight depressions and shallow swales found in the Miami sandy loam area, and owes its origin partly to transportation of the finer particles from the higher lying sandy loam areas,. although chiefly to lacustrine deposit during the early period of the recession of the glacial lake.

The soil is well adapted to wheat, oats, flax, barley and corn. As its ability to retain moisture is greater than that of the lighter soils it withstands drought better and crops are somewhat surer on this account.

The following table shows the mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF FARGO LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7457	¼ mile E. of NW. corner sec. 15, T. 150 N., R. 54 W.	Light loam, 0 to 12 inches	6.28	Tr.	1.60	3.30	39.74	15.74	25.50	13.54
7459	Subsoil of 7457	Light sandy loam, 48 to 60 inches	.79	0.20	.94	2.44	50.50	20.24	14.66	10.72
7458	Subsoil of 7457	Loam, 24 to 36 inches	1.60	.00	.98	3.14	40.38	15.74	16.78	22.2

MIAMI LOAM.

The Miami loam consists of from one to two feet of black to brown sandy loam of the same texture as the material composing the surafce soil of the Miami sandy loam. This material, without change in texture, grades into a yellow-colored soil beneath which occurs about one foot of gray or white gritty loam, often containing small gravel. This is in turn underlain to a depth of six feet with a mottled gray and yellow stiff, gritty loam or clay loam, containing a large proportion of small gravel. Usualy small concretions of iron oxide are present in the soil below the fourth foot. This subsoil is much like the corresponding section of Fargo gravelly loam and, like it, carries local beds of gypsum.

There are rarely large enough areas containing excessive amounts of alkali in the first three feet of the soil of this type to be indicated on a map of the scale used; that is, there is generally less than the minimum limit of 0.20 per cent. The subsoil, however, usually contains some alkali and often the amount is considerable.

This soil is found on the slopes of the eastern beaches of the old lake and in intervening areas, being typically developed at Emerado. The sandy loam surface is due to transportation and deposition of material carried over the beaches by the water during the recession of the lake. Some of the areas of the type owe their origin to transportation of sandy loam and sand from the top of the beaches into the swales between them, the sandy loam being really a covering over the Fargo gravelly loam.

The typical areas of this type are well adapted to wheat, oats, barley, millet and flax, though the lower-lying areas of the type, where the alkaline subsoil is near the surface, do not produce very good crops.

The following table gives mechanical analyses of this soil:

MECHANICAL ANALYSES OF MIAMI LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 3.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
7437	¼ mile S. of NE. corner sec. 2, T. 151 N., R. 52 W.	Sandy loam, 0 to 18 inches	5.74	1.68	4.74	9.12	12.16	20.64	41.12	10.54
7438	Subsoil of 7437	Loam or clay loam, 48 to 60 inches	.47	2.5[illegible]	3.90	3.96	10.74	9.34	48.14	21.42

MIAMI BLACK CLAY LOAM.

The Miami black clay loam consists of from one inch to four or five inches of muck or mucky loam underlain with black loam, often of a silty texture, to a depth of from one to two feet. Beneath this is about a foot of fine gray, usually silty, loam that nearly always grades into yellow silt loam at about three feet below the surface. This is in turn underlain to a depth of six feet with a mottled gray and yellow silty loam, sometimes becoming a silty clay loam in the

fifth or sixth foot. Almost invariably small concretions of iron oxide occur in the soil below the third foot. It is this iron that gives the soil its usual yellow color when a depth beyond the influence of dissolved organic matter is reached. The type is very fine in texture and usually does not contain a noticeable amount of sand. Local beds of crystalline gypsum often occur and are found at any depth in the profile.

For a distance of several miles west of Red River there is in the surface three feet of the Miami black clay loam very little alkali, but farther west, as far as the type has been mapped and especially around Ojata, where the natural drainage is poor, the amount of alkali is considerable. Black alkali was almost invariably found in both the surface soil and subsoil, the quantity varying from a trace to 0.05 per cent in the surface foot and usually a little less in the subsoil. The black alkali is, of course, not found in areas with free gypsum beds. There was also very often less than 0.20 per cent of soluble salt in the first three feet in these places.

Excepting the alkali areas, the Miami black clay loam is generally recognized as being a fine soil for wheat, oats, barley and flax. The type very well withstands moderate drought, the subsoil being always in fine, moist condition. It would be an excellent soil for celery in seasons of good rainfall.

The area over which this soil occurs is very level, broken only by a few shallow creek depressions which do not at all interfere with cultivation. (See figure OO.)

This soil is a lacustrine deposit and is the only type in the area that has not been modified by other action since the original deposition.

The following table shows the texture of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

No.	Locality	Description	Organic matter — per cent	Gravel, 2 to 1 mm. —per cent	Coarse sand 1 to 0.5 mm.—per cent	Medium sand, 0.5 to 0.25 mm.—per cent	Fine sand, 0.25 to 0.1 mm.—per cent	Very fine sand, 0.1 to 0.05 mm.—per cent	Silt, 0.05 to 0.005 mm. —per cent	Clay, 0.005 to 0.0001 mm. —per cent
7442	W. center sec. 36, T. 151 N., R. 51 W.......	Loam, 0 to 12 inches.....	5.67	0.00	0.20	0 20	1.66	17.10	75.04	4.94
7439	N. center sec. 91, T. 151 N., R. 52 W......	Loam, 0 to 12 inches.....	4.02	.36	1.14	1.22	3.56	5.70	64.78	22.88
7443	Subsoil of 7442.........	Silty loam, 24 to 36 inches	.65	.12	.54	.40	.70	9.36	83 82	4.18
7444	Subsoil of 7442	Silty loam, 48 to 60 inches	.46	.0	.36	.30	.56	3.22	79.78	14.82
7440	Subsoil of 7439.........	Silty loam, 24 to 36 inches	.79	.20	.72	.38	.68	4.06	77.42	16.34
7441	Subsoil of 7439	Silty loam, 48 to 60 inches	.53	.16	.60	.50	1.00	2.70	73.12	21.68

MUCK.

The muck soil is found in many places in different parts of the area, the individual areas varying in size from an acre or less to about one square mile. The type consists of from one to three feet of muck, underlain by sandy loam or sand or, rarely, by loam. This is in turn underlain by sandy loam to a depth of six feet.

Muck is found in local depressions, such as kettle holes and swales and generally along the creek courses and in swamps. It is due to gradual accumulation and decomposition of organic matter resulting from the rank grasses which in this area appear to be about the only vegetation growing in these swampy places. In the spring of the year the areas are usually wet and swampy, but during summer they become dry enough to allow the cutting of the grasses for hay.

No alkali exists in this type, its absence being chiefly due to the the light subsoil, as, aside from percolation downward, these areas are usually poorly drained.

UNDERGROUND WATER.

No general relation seemed to exist between the salt content of the soil and the water table, except where the latter was within three feet or so of the surface, when there was generally a noticeable increase of salt in the surface foot of soil.

The following table shows the results of field analyses of well waters in all parts of the area. With but few exceptions the shallow wells contained less soluble salts than the deeper, and especially the flowing wells. The alkali content of the last ranged from 420 to 1,430 parts of soluble salt per 100,000 parts of water, the salts consisting mostly of chlorides, with sulphates second. The deep and the flowing wells generally contain less of the bicarbonates than the shallow wells.

CHEMICAL ANALYSES OF WELL WATERS

No. of sample	Location	Depth in feet	Parts of salt per 100,000			
			Total salt content	Bicarbonates	Chlorides	Sulphates *a*
14	¼ mile E. of SW. corner sec. 8, 151 N., R. 51 W........	....	250	49	12	189
15	N. center sec. 7, T. 151 N., R. 50 W....................	(*b*)	540	42	276	212
52	NE. corner sec. 16, T. 1 1, N., R. 50 W.	(*b*)	420	38	260	122
52½	Same place as sample 52..................................	5	55	(*c*)	(*c*)	(*c*)
59	SW. corner sec. 2, T. 151 N., R. 50 W...................	6	130	89	9	32
80	¼ mile N. of SW. corner sec. 34, T. 151 N., R. 50 W...	75	90	(*c*)	(*c*)	(*c*)
81	¼ mile W. of SE. corner sec. 34, T. 51 N., R. 50 W....	7	40	(*c*)	(*c*)	(*c*)
91	½ mile W. of NE. corner sec. 11, T. 150 N., R. 50 W....	....	130	67	5	58
93	W. center sec. 3, T. 150 N., R. 50 W....................		90	(*c*)	(*c*)	(*c*)
106	NE. corner sec. 32, T. 151 N., R. 50 W..................		55	(*c*)	(*c*)	(*c*)
171	S. center sec. 6, T. 150 N., R. 54 W....................		70	63	Tr.	107
178	N. center sec. 11, T. 151 N., R. 55 W...................	16	28	(*c*)	(*c*)	(*c*)
183	NE. corner sec. 4, T. 151 N., R. 55 W...................		60	52	7	None
190	⅛ mile E. of SW. corner sec. 17, T. 151 N., R. 55 W....	40	250	53	64	133
209	NE. corner sec. 33, T. 1 1 N., R. 55 W..................	18	60	58	3	None
215	NE. corner sec. 29, T, 151 N., R. 55 W..................	15	360	50	58	252
217	NE. corner sec. 31, T. 151 N., R. 55 W..................	9	320	50	58	212
227	SW, corner sec. 33, T. 151 N., R. 55 W..................	10	170	67	21	82
230	¼ mile E. of SW. corner sec. 5, T. 150 N., R. 55 W.....	60	180	71	21	88
245	SE. corner sec. 34, T. 151 N., R. 55 W..................	....	220	60	21	139
316	SE. corner sec. 25, T. 150 N., R. 54 W..................	8	135	58	3	74
334	SE. corner sec. 26, T. 151 N., R. 53 W..................	10	135	78	12	45
354	⅛ mile N. of SE. corner sec. 1, T. 151 N., R. 54 W.....	....	465	87	12	366
374	E. center sec. 12, T. 151 N., R. 54 W...................	150	560	63	7	490
397	S. center sec. 23, T. 151 N., R. 53 W...................	9	180	73	23	None
420	¼ mile S. of NW. corner of sec. 4, T. 150 N., R. 53 W..	9	250	55	Tr.	195
450	N. center sec. 11, T. 151 N., R. 52 W...................	9	110	53	63	None
456	¼ mile W. of NE. corner sec. 1, T. 151 N., R. 52 W.....	(*b*)	490	42	290	158
473	S. center sec. 16, T. 151 N., R. 52 W...................	4	340	52	16	272
493	SE. corner see. 24, T. 151 N., R. 52 W..................	*b*33	560	42	302	216
335	SE. corner sec. 26; T. 151 N., R. 53 W..................	80	130	80	12	38
519	SE. corner sec. 27, T. 151 N., R. 52 W..................	*b*130	520	73	358	89
529	N. center sec. 35, T. 151 N., R. 52 W...................	*b*44	420	53	202	165
533	¼ mile W. of SE. corner sec. 11, T. 151 N., R. 52 W....	(*b*)	430	50	81	567
536	NE. corner sec. 13, T. 151 N., R. 52 W..................	6	70	50	14	None
564	SW. corner sec. 30, T. 151 N., R. 51 W..................	*b*135	660	45	441	174
578	N. center sec. 1, T. 151 N., R. 51 W....................	....	720	50	346	324

a Sulphates computed by taking the difference between total salt content and bicarbonates and chlorides.
b Flowing.
c Quantity not determined.

ALKALI IN SOILS.

The map showing the alkali in the soil, departs from the general rule of such maps previously made for areas lying in irrigated and arid regions in one particular, viz, it is based upon the mean amount

of salts in the first three feet of soil instead of upon the mean in the first six feet. The difference in climatic conditions and the fact that shallow-rooted crops form almost exclusively the agriculture of the area made it seem unnecessary to use the more extended profile in this case. It is even thought that a map based on the shallower borings will be of greater value than one where the deeper subsoil was taken into the calculations.

In the Grand Forks area there is generally enough precipitation to prevent the salt in the subsoil from lodging permanently in the surface soil through capillary action, and the roots of the crops commonly grown do not usually, perhaps never, reach deeper than three feet. The fact that alkali below this depth, or even at two or three feet, can have little or no effect on the crop growth was conclusively proved by the condition of the crops seen during the survey. Irrigation is not practiced in the areas, and probably never will be extensively practiced, so that the vertical distribution of the salts will not, as in other alkali areas, be affected artificially, and as long as the present method of farming continues in the area there seems no probability that the salts in the subsoil will rise.

A number of determinations were made, however, to depths of six and of eight feet, for the purpose of studying the vertical distribution of the salts in the subsoil. No alkali was found in the Miami sandy loam, even at a depth of six feet, and not enough in the first three feet of Fargo gravelly loam to map, though considerable quantities were present in the subsoil. The conditions in the case of the Miami loam were similar to those of the Fargo gravelly loam, as typically developed, and in these two types alkali would have been much more general had the salt map been based on the mean of six-foot borings instead of three-foot borings, and the conditions would have apparently been much worse than they actually are. Very little alkali was found in the Fargo loam in the first three feet, and none was found in the subsoil, as this was much lighter in texture than the soil.

The two types containing injurious amounts of alkali in the first three feet, as well as in the deeper soil, are the Miami black clay loam and the valley phase of the Fargo gravelly loam. As shown by the alkali map, the greater part of these two soils carry an average of more than 0.20 per cent of soluble salt at soil saturation in the first three feet, and if the map had been constructed to six feet

the conditions would have appeared worse in practically all parts of these areas.

The worst alkali conditions were found in township 151 N., ranges 51 and 52 W. This includes most of the strictly lacustrine deposit soils, as the surface soils west of Emerado have been modified by secondary deposits since the lacustrine subsoil was laid down.

Two ways suggest themselves in which the alkali may have originated. It may have reached the surface by the capillary movement of the salt-carrying, deep-seated waters percolating the underlying drift or Cretaceous shales, assisted by the natural pressure to which these substrata are subjected, or it may have been deposited with the lacustrine material either by being in solution in the lake water, which may have been concentrated, or as being originally in the soil washed into the lake. It does not appear that the lake water ever reached a high state of concentration and this theory is hardly likely, the origin of the lake considered.

The soil borings can be of little value in determining the origin, except so far as they show the constitution of the alkali. Considerable information on this point is obtained by a study of the table of analyses of well waters given on a preceding page. It is undoubtedly fair to assume that the relation of the salt constituents in the well waters agrees approximately with the solution in the soil from which the water is derived.

The chemical analysis of the standardization solution made in the Bureau laboratory conclusively shows the great preponderance of the acids to be sulphates, these constituting, in fact, more than half of the total amount of salts, with chlorides second, but by no means in large quantities. This solution represents all depths of alkali soils from surface crusts to soil six feet below the surface. The various titrations made on soil samples in all parts of the area by the party in the field also brought out the fact that sulphates were generally in excess of any other salt. An inspection of the table of well-water analyses will show that the shallower wells, with but very few exceptions, show sulphates greatly in excess of chlorides.

As no method for the determination of sulphate quantitatively in the field has been devised, these were estimated by difference. The total amount of salt, the chlorides, the carbonates, and the bicarbonates were determined electrically and volumetrically, and it was assumed that the difference between the total amount of salt

and the sum of the other constituents mentioned was equal to the sulphates. The results of this method are not, of course, strictly accurate, but are sufficiently so for the purpose of discussion, as no other salts were reported in the complete chemical analyses made in the laboratories.

By referring to the above mentioned table it will be seen that the chlorides and sulphates occur in altogether different relation in the deeper wells, and especially in the flowing wells, than they do in the shallower wells, i. e., wells with a depth of twenty feet or so. There are apparently exceptions, as for instance in Nos. 230 and 335, but as the surface water was not excluded from the deeper seated strata these are of no consequence. The chlorides are in every instance in excess of the sulphates in these deep wells, while in the shallower wells the sulphates are largely in excess. Considered along with this that beds of sulphates, especially gypsum, are quite numerous in the lacustrine deposit and distributed over the entire lacustrine area—Miami black clay loam and valley phase of the Fargo gravelly loam—one cannot but conclude that the alkali in the alluvial area in the surface soils was deposited with the soils at the time these were laid down in the lake, and that the alkali water from the deeper and flowing wells belongs to another formation probably the underlying Cretaceous shales.

With but few exceptions the quantity of salt was found to increase downward. The maximum found was about three per cent in the dry soil, and in the worse alkali districts this quantity was found at from three to six feet. No maximum was found in any one particular foot section, but when once the three per cent was reached there was no diminution.

Black alkali was very often, in fact generally, found, even in the presence of small amounts of sulphates, in both soil and subsoil. It was particularly likely to occur in the surface foot, the amounts varying from a trace to 0.07 per cent, though this latter figure was reached in but one place. As much as 0.05 per cent was found in a number of places, but the distribution was not sufficiently extensive or general to warrant the construction of a separate black alkali map.

Good crops of grain, flax, and millet were often found growing on the alkali soils, even where the average amount of salt in the first three feet ranged from one to three per cent. This was due

often to the unequal vertical distribution of the alkali, the surfac foot carrying but a small part of the total amount. In arid region such amounts of alkali would with certainty kill any but the mos resistant salt grasses, and some areas where most vegetation ha succumbed were found in the area surveyed, while in the wors alkali district, in and around Ojata, bare spots were common, thes containing a surface deposit of alkali, where even salt grasses an alkali weeds could not exist. However, very fair crops were foun to be growing even where the surface foot carried what woul usually be considered excessive amounts of salt for agricultura crops.

The table on the following page, while not intended at all to de fine the exact salt conditions under which crops will or will nc grow, shows at least conditions as found in the area surveyed.

TABLE SHOWING THE RELATION OF THE CONDITION OF GROWING CROP TO THE PERCENTAGE OF ALKALI IN THE FIRST FOOT OF SOIL IN THE GRAND FORKS AREA

Crops	Condition			
	Good Crop	Fair Crop	Poor Crop	Killed
	Per cent	Per cent	Per cent	Per cen
Wheat	0.30	....	....	0.[illegible]
	.39	....	....	[illegible]
	.46	....	....	....
Oats	.39	0.58	0.63	....
	.46	....	.84	....
	.51	....	....	....
Barley	.31	.44	.70	....
	.43	.46	....	....
Flax	.32	.37	.52	[illegible]
	.38	.55	.64	[illegible]
Prairie grass and salt grasses	1.16	1.50	....	....
	1.20	2.00	....	....

There are, of course, different crop conditions with the sam salt content in the surface foot of soil, as many factors enter int discussion, such as late or early seeding, presence or absence o favorable proportion of moisture in the soil, etc. As these condi tions were found in the fall of the year when the crops were ma tured there can be no doubt about the observations. It should als be kept in mind that in every instance the salt content increase in lower depths, the third foot section carrying more than one pe cent of alkali in some cases where good crops were growing.

There is but one way to reclaim the alkali flats so that they wi grow agricultural crops profitably, viz. by draining them artificiall

The subsoil is too heavy in all places to accomplish drainage otherwise. The alkali area in and around Ojata could be drained into the swamps and shallower creek beds or sloughs found there. It would, however, involve quite an outlay of capital, and under present agricultural conditions would probably not be profitable. The drains, however, would not need to be laid as deep as in the more arid regions, as the greater rainfall washes the salts down from the surface and it is not necessary to control accumulation through evaporation. These alkali flats are, however, valuable even in their present condition, as the native grasses growing on the greater part of them make very good hay when properly cured.

CHEMICAL ANALYSES OF ALKALI SOILS AND CRUSTS

Constituent	7460. ¼ mile E. of University; alkali crust.	7461. ¼ mile W. of NE. corner sec. 12, T. 151 N., R. 51 W., alkali crust.	7462. ¼ mile W. of NE. corner sec. 12, T. 151 N., R. 51 W., subsoil 12 to 36 inches.	7463. ⅛ mile S. of NW. corner sec. 6, T. 151 N., R. 50 W., subsoil 4 to 6 feet.	7464. ⅛ mile E. of SW. corner sec. 22, T. 151 N., R. 50 W., alkali crust.	7465. ¼ mile S. of NW. corner sec. 10, T. 151 N., R. 50 W., alkali crust.	7466. West center sec. 31, T. 150 N., R. 55 W., subsoil 12 to 36 inches.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ions:							
Calcium (Ca)	6.74	5.83	16.82	13.31	1.76	7.34	24.56
Magnesium (Mg)	14.34	10.74	7.12	5.89	.81	14.24	1.55
Sodium (Na)	1.13	10.69	1.15	1.96	28.44	1.13	.94
Potassium (K)	1.42	.95	2.88	11.44	1.00	.59	1.55
Sulphuric acid (SO_4)	73.94	47.12	59.71	41.93	65.49	73.99	68.94
Chlorine (Cl)	.77	23.59	9.16	20.11	.64	1.56	.64
Bicarbonic acid (HCO_3)	1.66	1.08	3.16	5.36	1.86	1.15	1.82
Conventional combinations:							
Calcium sulphate ($CaSO_4$)	22.28	19.82	57.10	26.45	5.97	24.97	83.4[illegible]
Magnesium sulphate ($MgSO_4$)	70.99	41.49	24.31	29.22	4.04	70.64	9.9[illegible]
Sodium sulphate (Na_2SO_4)	2.55	......	....	......	85.91	......	2.3[illegible]
Potassium chloride (KCl)	1.63	1.81	5.50	21.81	1.35	1.71	1.[illegible]
Sodium carbonate ($NaHCO_3$)	1.09	1.49	4.29	......	1.99	1.58	.[illegible]
Magnesium chloride ($MgCl_2$)	......	9.24	8.80	......	......	......	....
Sodium chloride (NaCl)	......	26.15	......	......	......	1.70	....
Calcium chloride ($CaCl_2$)	......	.....	......	15.19	......	......	....
Per cent soluble	10.79	15.50	3.82	2.24	12.96	12.52	5[illegible]

Part of the sodium, varying from 0.24 per cent in sample 74[illegible], to 2.17 per cent in sample 7460, was probably in combination with organic acids, and is therefore not shown in the foregoing table.

AGRICULTURAL METHODS.

The principal products grown are wheat, oats, barley, flax, millet, and hay. Some vegetables are produced for the market, but not much importance is given to this branch of farming. The hay lands are confined chiefly to the low-lying and naturally swampy areas.

Wheat is by far the most important crop grown, and the product is very favorably known all over the country for its quality. The wheat is all spring sown and of the hard variety. In 1902 there was a greater area in the county devoted to wheat than to all other crops combined. In the same year flax was second in acreage, it having been grown much more generally that year than ever before. The increase that year was no doubt partly due to a desire to carry on more diversified farming, but also largely to the fact that the season was quite late and much of the land not dry enough in time to allow wheat or oats to mature. Millet was likewise grown more largely in 1902 than in any other year, which was also mainly due to a late spring. These two crops need less time to mature than do the cereals, and hence they are sometimes used as emergency crops.

Flax, however, is generally conceded to be an unprofitable crop to grow on the same piece of land for more than two successive years, owing to a peculiar disease known as "flax wilt." The trouble is due to a fungus which appears to be introduced with the seed. When affected the plants turn yellow and partly wilt, and are considerably stunted in growth. If by chance they mature—which a badly affected plant does not—the seed is smaller than the average flaxseed and of a very inferior quality. There seems to be no remedy yet discovered for the disease, and farmers are recommended by the experiment stations to take great care in selecting their seed and to treat it with formaldehyde. The crop is grown almost exclusively for the seed, nothing being as yet done with the fiber excepting a small amount used at Fargo for making hemp. Plans are being seriously considered, however, for putting in machinery at that place (the plant now is small) which would utilize more of the straw and make the industry more general.

There is but little systematic rotation of crops practiced. A number of instances were met with where farmers had planted wheat for eighteen or twenty years without any other crop as alternate, the only break in the scheme being two or three years of summer fallowing. The effect of such constant cropping is quite readily noticed in some parts of the area, though much of the land continues to yield apparently as good crops as ever. When land is considered in need of "rest" it is generally summer fallowed. A decidedly better plan would be to alternate with hoed crops of some kind, but

as the farms are generally extensive in area it does not seem to be considered worth while to expend the labor necessary to the production of such crops. More diversified farming could, however, be profitably introduced. Similarly little attention is paid to adaptation of crops to soils, any crop being planted on any kind of land.

Plowing is generally done in the fall, often before the grain is thrashed. This enables the seeding of the land to be done earlier in the spring than when plowing is left until spring, and this is an important matter on account of the shortness of the growing season. It is also a good practice in that it leaves the soil in a better condition for nourishing the next year's crop, as the weathering processes going on during the winter materially increase the available plant food. Especially is this true of the heavier soils.

The amount of seed sown to the acre varies widely, differing with the soil conditions and individual opinion. Any quantity from one and a quarter to three bushels of wheat per acre is sown, and adherents of both extremes claim the better results. Certain it is, however, that more seed is needed in late sowing than in early sowing, in order that too much stooling may be prevented and the crop forced to maturity as early as possible.

Grain harvesting is done altogether with the binder, and the thrashing is done by steam power. Usually the grain is not stacked, but is hauled direct from the shock to the thrasher. Considerable time, trouble, and expense are thus saved; but there is a slight loss attending this method, as wheat, especially, will usually sell a grade better if allowed to pass through the "sweating" process in the stack. It is generally considered, however, that the higher price received is not sufficient to warrant the trouble and expense of stacking.

The yields vary quite widely in different parts of the area, even on the same soil types, the variation depending on a number of factors. It is considered by unprejudiced observers that the average yield per acre is about twelve or fifteen bushels of wheat, and this is probably a low enough figure. Forty bushels per acre have been raised with favorable circumstances. Barley yields, on the average, from twenty-five to thirty bushels, and oats from thirty-five to forty bushels per acre. Flax, which is becoming an important crop, averages about fifteen bushels per acre. As before mentioned, this crop does better on land that has not been seeded to

flax for a number of years. An interesting case was met with in the area, where a piece of land had yielded twenty-five bushels per acre the first year—a big crop—twenty bushels the second, fifteen bushels the third, and about twelve to fifteen bushels the fourth year. This, however, was on a choice piece of land, and where good care had been given the crops.

Very little fruit has yet been raised or attempted to be raised in the county, the climate being too severe for any but the most hardy sorts.

AGRICULTURAL CONDITIONS.

The agricultural conditions of the state at large have improved greatly and in almost every respect during the last decade. In that time the cultivated area and the number of farms have increased nearly 100 per cent, the acreage per farm has increased from 277 to 343 acres, and the value of farm lands, improvements, buildings, live stock, etc., has almost doubled.

The number of acres in farms in Grand Forks county in 1900 was 861,872. There were 2,368 farms. The average size of farms was 364 acres, and the average value of each, exclusive of buildings and improvements, was $6,327. About 87 per cent of the farm land in the county is improved, and more is constantly being brought under cultivation. Generally speaking, the buildings and improvements are good, especially on the better lands, and the farmers are well supplied with the necessary live stock and implements for the successful operation of their farms.

The population of Grand Forks county is composed almost entirely of the farming class, and little interest is taken in stock raising except as an adjunct to the economical operation of the farm. The proportion of the farmers of Grand Forks county owning farms cannot be definitely stated, but for the whole state 91.5 per cent of the farms are operated by the owners and 7.2 per cent are operated by share tenants. This would probably be a very fair estimate of the conditions of tenure in the county. Some of the farms classed as operated by the owners, especially the larger farms, are in charge of managers appointed by the owners. The managers have general supervision of affairs and receive a fixed remuneration for their services. Quite often farms are operated by the owners and tenants in conjunction, the tenants receiving a share of the products.

Considerable labor is hired during the busy seasons of the year, and especially at harvest time. This being temporary employment, the laborer is paid considerably more than where the service is permanent, $2.50 to $3 per day for single hands being quite common, the work being shocking grain, assisting in thrashing, plowing, etc. Labor by the month or year is paid much less. According to a report of the county auditor, there were employed on the farms of the county, in 1901, 1,675 male and 347 female employees. According to the same authority, the average wages paid were $24.25 and $13 per month, respectively. There is very little colored help employed in the county.

The transportation facilities of the county are good. The main line of the Great Northern passes through the area from east to west, and a number of branches of this system radiate from Larimore and Grand Forks. The Northern Pacific system also touches the area, passing through Grand Forks.

Along the railroads, at frequent intervals and convenient points, there are small stations, each with from one to half a dozen elevators for storing products temporarily to await shipment. Few farmers have granaries of their own, but deliver their grain to the elevators immediately after it is thrashed, thus usually disposing of it at a lower price than could be obtained later in the year. But as the country is practically new and as many of the farmers have had to pay for their land in yearly payments, many of them are not yet in condition to hold their crop.

A prominent feature of the agriculture of the county is the operation of large farms. These frequently range between 1,000 and 5,000 acres, and in one—the largest in the county, and reported to be the largest grain farm in the world—11,000 acres were sown to crops in 1902. A movement is on foot, however, to have this place divided up into quarter sections and sold to colonists. This would introduce a more diversified farming, dairying, etc., and would be a good thing for the county. Some of the other owners of large farms are seriously considering doing the same thing, and better agricultural conditions will soon obtain if the plan is carried out.

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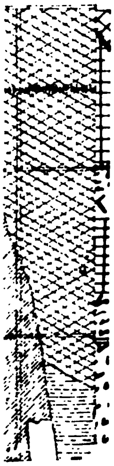

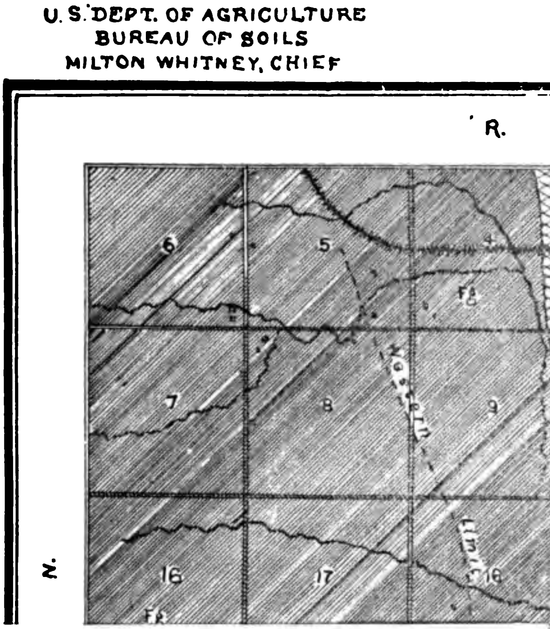

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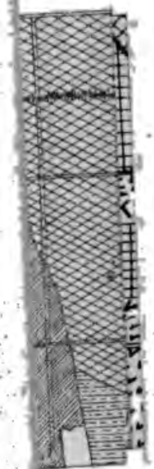

SOIL SURVEY OF THE FARGO AREA.

By Thomas A. Caine.

Field Operations Bureau of Soils, 1903.

LOCATION AND BOUNDARIES OF THE AREA.

The Fargo area lies wholly within Cass county, one of the eastern tier of counties, and represents a typical section of the Red River valley from the Red River on the east to the highest shore line of glacial Lake Agassiz on the west.

It is confined within meridians ninety-six, fifty-one minutes, twenty-six seconds and ninety-seven degrees, thirty-two minutes, nine seconds west logitude and parallels forty-six degrees, forty-seven minutes, thirty-three seconds and forty-six degrees, fifty-seven minutes forty-seven seconds north latitude, and consists of townships 139 and 140, ranges 49 to 54 west, inclusive. There are 259,776 acres, or approximately 406 square miles, in the area.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The first white settlement in the Red River basin was as early as 1816, when the Selkirk colony, coming via Hudson Bay, settled in the vicinity of Winnipeg. From that time until about the middle of the century fur trading was the only occupation of the white settlers of the region.

In 1851 a few white settlers obtained some land from the Sioux Indians for agricultural purposes, but the Indians were so troublesome that these early attempts at agriculture were unsuccessful.

It was not until late in the seventies, after the Northern Pacific and Great Northern railways had penetrated the region, that the special adaptation of the soil for wheat became generally known. From 1875 to 1885 the settlement of the region was pushed forward very rapidly, nearly all of the land in the valley being taken up during these years by homestead or preemption claims from the government, or by purchase from railroad corporations of land which they had received from the government as grants. Agricultural development was very rapid along the main lines of these railroads, and branches were soon built which greatly increased the shipping facilities of the area and resulted in a great impetus to farming. Many settlers flocked in from the older states and many came from the Old World, especially from Norway, Sweden, and

Denmark. In 1889 Dakota territory was divided, and two states, North Dakota and South Dakota, were admitted to the Union. During the last decade land values in the area have nearly doubled, and the prospects are for still higher values. During the last few years more stock has been introduced into the country, and there is a strong tendency toward more diversified farming and better cultural methods.

CLIMATE.

Owing to the absence of timber lands and the geographic position of the area in the center of a large continent and at a high latitude, the difference between the temperature of summer and winter is very great. Usually there are only a few days in summer when the mercury gets as high as 100 degrees F., and the nights are always cool. The seasons are sharply defined. The growing season opens suddenly in April, when the surface of the ground thaws rapidly, permitting seeding in a few days. Winter is generally ushered in by a sudden cold wave in November, when the ground freezes and the fall plowing is stopped.

During the months of January and February the temperature is often from 10 degrees F. to 30 degrees F. below zero for days at a time, but owing to the dryness of the atmosphere this low temperature is not as difficult to endure as a much higher temperature along the coasts or lakes, where the humidity is usually greater.

The region may be classed as subhumid, the normal rainfall being about 23 inches. The following table, compiled from records of the Weather Bureau stations at Power and Wahpeton, N. Dak., and Moorhead, Minn. (across the river from Fargo, N. D.) shows the normal monthly and annual temperature and precipitation:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Power		Wahpeton		Moorhead	
	Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches	Temperature—degrees F	Precipitation—inches
January	11.4	0.50	9.0	0.34	0.9	0.73
February	7.0	.60	9.4	.59	4.5	.83
March	19.0	1.59	24.0	2.63	20.2	.87
April	41.0	1.88	46.0	2.45	41.3	2.23
May	54.0	1.99	58.0	2.99	53.2	2.50
June	65.0	3.73	66.0	4.27	64.8	4.36
July	69.0	3.80	70.0	4.12	67.6	3.91
August	67.0	1.79	68.0	2.83	65.2	2.68
September	60.0	1.16	61.0	1.44	56.5	2.09
October	45.0	1.35	46.0	1.35	43.1	1.92
November	23.0	.61	26.0	.60	24.2	.92
December	13.0	.82	16.0	.35	11.9	.72
Year	39.5	19.82	41.6	23.96	37.6	23.77

A study of the records of temperature year by year seems to indicate that the winters are less severe than formerly, the greatest change being in January and February. In those months there has been a decided increase in temperature, while in March, April and May the difference is less marked, and during the remainder of the year the conditions have been more constant. The milder winter is a fact well recognized by all farmers who have lived in the valley for a score or more of years.

Owing to the difficulty of getting onto the fields early enough in the spring to plow for seeding, nearly all of the plowing is done in the fall after harvest. This exposes the black soil characteristic of the valley to the sun during the winter months. The rainfall is greatest during June and July, the months when it is needed most by the growing crops. During January and February, the months in which there has been the greatest increase in temperature, the average precipitation is less than one inch. The small amount of snow that falls during these months is no longer lodged in the prairie grass as formerly, but is either blown off the plowed fields into the coulees or is melted upon the heat-absorbing black soil during the bright days. Before the country was broken up this snow was held in the prairie grass. A perfectly black body has the property of absorbing all radiations which fall upon it, and this increases its temperature. In the case of a black soil a part of the heat thus absorbed is again radiated, while a part of it is conducted away to other portions of the soil mass not exposed directly to radiation. The temperature of the soil, as a whole, is thus raised, and by radiation the soil warms the air to some extent. A perfectly re-

flecting body, on the other hand, which would in a way be approximated by the light-colored prairie grass and the white snow, would reflect all the radiation falling upon it without any corresponding rise in temperature. This may account for the change in winter temperature thought to have taken place in this region.

The term "killing frost" represents a frost which will kill such crops as are generally grown in the valley, and usually represents a temperature of 26 degrees F. If fruits or other more delicate crops were grown in the valley a higher temperature would have to be taken as indicating a killing frost. The average dates of killing frosts, based on records covering a period of twenty-two years, are as follows: Last in spring, May 14; first in fall, September 20.

PHYSIOGRAPHY AND GEOLOGY.

In preglacial times there was a broad, well-defined valley, cut through the soft, Cretaceous shale, sloping northward from the vicinity of what is now Lake Traverse, S. Dak., past Winnipeg, Manitoba, to Hudson Bay.

During Glacial times the bottom of this valley became covered to a considerable thickness with glacial debris or till, and when the ice sheet retreated northward it became filled with water from the melting ice, and a lake was formed, with its southern end near Lake Traverse, and extending northward into Canada. This lake is known as Lake Agassiz. The width varied, but when the water was at its highest level the average width was about 45 miles. The great ice barrier to the northward would not permit the water to flow in that direction, and the natural drainage during this period was southward over the lowest rim of the basin and through Big Stone Lake.

The melting ice furnished an abundance of water, and rapid glacial streams carrying rock fragments of all sorts and sizes, as well as finer materials, deposited them in the bottom of this great lake. The material carried in by the streams was sorted by the action of water, the heavy sand and gravel being dropped in the shallow water along the shore, there to be reworked by the waves and piled up by them into beaches, and the finer materials, silt and clay, being carried in suspension and deposited in the deeper water.

When the climate became warm enough to lower the ice dam below the level of the southern outlet of the lake, the water again

began flowing northward. The different beaches along the bottom of the old lake represent the different levels at which the water stood while the ice dam was being thawed away, and finally, when the ice was entirely removed, all but a portion, Lake Winnipeg, which was below the natural drainage channel, became dry.

The old lake bottom is now one of the most productive wheat-growing regions in the world, and is known as the Red River Valley, taking the name from the Red River of the North, which flows through it northward into Lake Winnipeg and thence through the Nelson River into Hudson Bay.

The Red River Valley is remarkably level, having a continuous, uniform slope northward of about 1 foot to the mile. The river itself flows along the lowest portion of the plain, and is very sluggish and meandering in its course. For the first 10 or 15 miles east and west from the stream the country rises imperceptibly, the average elevation being about 1 foot for every 5 miles.

The area surveyed comprises a typical section of the Red River Valley, extending from the Red River at Fargo westward beyond the highest shore line of the ancient lake. For the first 15 miles or so west at Fargo there are only about 3 feet difference in elevation. In the next 10 miles there is a gradual rise of about 8 feet to the mile. From Wheatland to the western edge of the area, a distance of 8 miles, there is a gradual rise of 22½ feet to the mile. From the Red River at Fargo westward to this point, a distance of 35 miles, there is a difference in elevation of 238 feet. Fargo has an altitude of 900 feet.

The highest shore line of the lake is represented by an abrupt beach which crosses the area at Magnolia in a northeast-southwest direction. The glacial till area to the westward is characterized by its rolling surface, made up of low hills, knolls, and kettle holes, and by the presence of rocks of all sizes strewn about the surface and disseminated through both soil and subsoil. This glacial till area passes under the lacustrine deposits to the eastward at a gentle angle. In several places in the western part of the lake area the knolls and hills of the underlying till come so close to the surface as to appear in the borings and along streams and in road cuts.

In places the distinct beach which passes through Wheatland appears to be made up largely of an escarpment of glacial till. At Casselton, 7 miles farther east, the underlying till is covered with the

lake deposit to a depth of 70 feet. At Fargo the till lies more than 100 feet below the surface deposit of lacustrine silt and clay.

While the surface of the lowest portion of the valley is practically flat, there have been some marked changes since the original deposition. For example, the Red River and its tributaries, the Sheyenne and Maple rivers, have cut channels into the silt and clay, and during freshets have overflowed, building up the lands immediately adjoining, which now are higher than the country a few miles away. This higher ground, both because of its looser texture and its better condition as to drainage, is more satisfactory for farming than the lower ground. The deep black soil characteristic of the middle portion of the valley doubtless results from peculiar conditions once obtaining in this lower lying area, which for many years after the recession of the lake was an extensive marsh.

The rocks from which the soils of the valley were originally derived can be seen in the lake beaches, and consist largely of granite, gneiss, limestone, and, to a small extent, of Cretaceous shale. But the latter rock has entered into the composition of the soil to a much greater extent than would appear from its relative proportion in the beaches, for it is very soft and much more easly ground to a flour by the glacier than the harder granite, gneiss, and limestone. Chemical analyses of the water from the underlying Cretaceous shale and a field analysis of a piece of pulverized shale taken from a well shows that it is quite alkaline. The fact that the alkaline rocks of the Cretaceous formation have entered largely into the composition of all the soils of the region accounts for the presence of alkali in all parts of the area.

SOILS.

Eight distinct types of soil were recognized and mapped in the Fargo area: The Marshall clay, Fargo clay, Miami black clay loam, Miami loam, Marshall gravelly loam, Marshall loam, Wheatland sand, and Wheatland sandy loam. The last-named type is unmodified glacial till; the other types are composed of the materials of this till sorted by water and more or less modified by weathering. The soils owe their distribution largely to the action of water, either of the glacial streams flowing into Lake Agassiz or of the lake itself. Thus, along the ancient shore is found a beach composed of coarse sand and gravel. Just east of this is found a sand class

and mapped as Wheatland sand. Toward the middle of the lake occur the soils classified as loams, clay loams, and clays.

The regularity of the separation, sorting, and deposition of the glacial till material was more or less interfered with by the fact that as the ice sheet retreated to the north the lake stood at lower levels. These levels are represented by several parallel beaches.

The area of the several soil types is given in the following table:

AREAS OF DIFFERENT SOILS.

Soil	Acres	Per cent	Soil	Acres	Per cent
Marshall clay	76.800	29.6	Miami loam	11,968	4.6
Miami black clay loam	74.880	28.8	Marshall loam	7, 68	2.7
Fargo clay	40,000	15.4	Marshall gravelly loam	2,688	1.0
Wheatland sand	29,501	11 4	Total	259,776	....
Wheatland sandy loam	16,768	6 5			

MARSHALL CLAY.

The soil of the Marshall clay is a jet-black clay loam or clay from 18 inches to 2 feet deep. The subsoil is a grayish-brown silty clay or clay extending to a depth of 6 feet. From 6 to 9 feet the texture remains the same, but the color changes. When exposed to the air the subsoil breaks up into thin flakes resembling shale or slate.

This type occurs in large bodies in the eastern part of the area, principally between Maple River and Red River. The areas upon which it is found are a little higher than the Fargo clay or "gumbo" areas, but the differences in elevation are slight and the surface may be considered level. The condition of the Marshall clay has been greatly improved in recent years by the construction of ditches along the roads of every section line. The most desirable phase of this type is found along the rivers where the ground is a little higher and the drainage conditions are better. This type is purely a lacustrine deposit, but perhaps somewhat modified by the overflow of rivers subsequently to the time when it was laid down.

No injurious amounts of alkali were found in the first 3 feet of this soil, but the alkali increases in the lower depths and excessive amounts were often found in the sixth foot. Traces of bicarbonates and some sulphates were usually found in the surface foot.

The Marshall clay is recognized as one of the strongest soils of the area and as well adapted to wheat, oats, barley, flax, and corn. Because of its somewhat imperfect drainage it can not be seeded

as early in the spring as can the lighter types to the westward, and consequently the crops mature later on this soil.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MARSHALL CLAY

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8451	NW. cor. sec. 24, Reed Tp.	Clay loam, 0 to 24 inches	5.31	Tr.	4.04	6.50	11.80	11.50	39.28	27.10
8453	NE. cor. sec. 35, Barnes Tp.	Heavy clay loam, 0 to 24 inches	5.48	.00	.54	1.36	6.80	10.92	49.38	30.66
8455	Fargo	Black clay loam, 0 to 30 inches	5.79	.74	7.78	7.74	10.56	7.48	33.80	31.94
8452	Subsoil of 8451	Brown clay, 24 to 40 inches	1.27	.00	.16	.30	2.38	4 20	57.00	36.00
8456	Subsoil of 8455	Clay, 30 to 72 inches	Tr.	00	.10	.20	1.10	2 20	38.06	58.26
8454	Subsoil of 8453	Gray clay, 24 to 40 inches	Tr.	.00	.30	.40	1.60	2.12	36.50	58.76

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$); No. 8452, 7.77 per cent; No. 8453, 1.20 per cent; No, 8451, 19.87 per cent; No. 8456, 14.58 per cent

FARGO CLAY.

The Fargo clay consists of from 6 to 14 inches of heavy black clay, underlain by gray or blue clay of the same texture to a depth of 5 feet. From 5 to 9 feet it is composed of a mottled gray-brown and yellow clay identical with the corresponding section of Marshall clay. When wet this type is very waxy and gummy and has an oily feel. It is exceedingly slippery under foot and often sticks to the wagon wheels in such quantities that they present the appearance of mud disks. During the wet seasons it is a common sight to see great piles of this mud, or "gumbo" as it is called, along the roads, where the farmers have stopped to clean their wagon wheels. When dry this soil can not be turned by the plow, which either rides on the surface or pushes to one side or ahead of it cemented portions of the soil sometimes a yard across. When wet it is also difficult to cultivate, as it sticks to the plow.

The Fargo clay is found in all parts of the area from the Red River westward to Wheatland. It is not found west of this village, the soils there being lighter and the drainage more perfect. This

type is always found in depressions, and, owing to the impervious nature of both soil and subsoil, water often stands upon the surface for weeks after a copious rain. The largest areas of the type are to be found between the Red and the Maple rivers in the vicinity of Fargo and Haggart, but small patches of it may be seen almost everywhere associated with the heavier types of soil.

Alkali is always present in this soil, but usually not in injurious quantities. Except in a few isolated patches excessive amounts were not found in the first foot, but in the second and third feet the increase was usually quite marked. In nearly all cases the average for the first 3 feet was between 0.15 and 0.20 per cent. A few isolated spots, not large enough to be mapped on the scale used, were found where the average of the first 3 feet was as high as 0.40 per cent. If an average for the first 6 feet had been taken instead of the first 3 feet nearly all the areas would show a salt content of about 0.40 per cent. The greater abundance of salts in the Marshall clay is the result of accumulation by leaching from higher lying lands. The peculiar waxy, gummy characteristic of the soil, it is suggested, may be due to the presence of small amounts of bicarbonates. The experiments of the college farm at Fargo show that by surface drainage, deep plowing and turning under coarse manures these textural peculiarities can be considerably modified.

This soil is regarded as one of the strongest and most productive in the area when the season is favorable. The great difficulty is to get the seed in early enough in the spring and to keep the land from flooding and from baking after rains. Crops are often injured as much by the baking of the soil after a rain as by a flood. Under the present imperfect condition of drainage, it is only about one year in five that the season is such as to give the best crops from this type. As a result these lands are held in low esteem for general farming. When seeded with brome grass, or covered with natural prairie grass, they are excellent for hay and pasture.

The following table shows the texture of the soil and subsoil of this type as determined by mechanical analyses:

MECHANICAL ANALYSES OF FARGO CLAY

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8464	SE. cor. sec. 2, Gill Tp...	Clay, 0 to 12 inches.......	3.63	0.20	1.30	1.10	4.00	9.50	37.82	46.C0
8458	N. cen. sec. 5, Everest Tp.....................	Black clay, 0 to 12 inches	2.66	.12	.60	.80	3.40	6.70	34 48	53.90
8465	Subsoil of 8464	Clay, waxy when wet, 12 to 24 inches	1.58	Tr.	.70	.70	2.08	5.80	27.00	63.36
8459	Subsoil of 8458	Waxy, impervious clay, 12 to 24 inches..........	2.22	.00	.26	.46	1.08	4.10	25.02	68.86

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$) No. 8458, 3.37 per cent; No. 8459, 2.59 per cent.

MIAMI BLACK CLAY LOAM.

The surface soil of the Miami black clay loam consists of about 14 inches of heavy gray or black loam, lighter in texture than the material of the Marshall clay. This is underlain by a silty clay loam to a depth of 36 inches, beneath which occurs a chalk-colored material, slightly coarser in texture, and reaching to a depth of 6 feet. In the lower depths this light-colored material becomes yellowish owing to the presence of iron oxide. Small beds of gypsum often occur in the second foot.

This soil type is found in a large, continuous body which extends across the area in a northeast-southwest direction from the vicinity of Maple River westward nearly to Wheatland. From the extreme eastern limit to the extreme western limit of the type there is a difference in elevation of nearly 60 feet. This gives a gradual rise of about 6 feet to the mile, so that the drainage conditions are more favorable than in any of the types to the eastward. Because of this and of the more porous nature of the subsoil, water seldom stands upon the surface long enough to cause injury to growing crops or to retard cultivation. This soil retains moisture well and gives it up in time of drought when the growing crops most need it. The soil is typically developed in the regions north and south of Casselton.

To a depth of 3 feet there are no injurious amounts of alkali in either soil or subsoil. Below that depth the amount sometimes becomes considerable. A trace of black alkali was found in the surface foot.

The Miami black clay loam is the soil which has contributed most to the fame of the Red River Valley as a wheat-growing district. As developed in this area, it seems especially well adapted to this crop, although in the Central West it is considered a typical corn soil, much less desirable for wheat than some of the prairie types. The rigorous climate of the Red River Valley is less suited to the production of corn than of wheat, and this fact has tended to limit the use of the Miami black clay loam to wheat production.

The extensive development of the Miami black clay loam in the valley, its generally smooth surface and good drainage, all favor the most extensive methods of farming, and there are probably no wheat farms in the world larger than those found in the Red River Valley.

The production of corn on this type is increasing, and it is thought that ultimately an early-ripening variety will be established and the risk of damage from freezing reduced to such a degree that corn will form an important crop of the area. Large yields of Irish potatoes can be produced on this type, but this crop is at present grown only for home consumption.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm.—per cent	Coarse sand 1 to 0.5 mm.—per cent	Medium sand, 0.5 to 0.25 mm.—per cent	Fine sand, 0.25 to 0.1 mm.—per cent	Very fine sand, 0.1 to 0.05 mm.—per cent	Silt, 0.05 to 0.005 mm.—per cent	Clay, 0.005 to 0.0001 mm.—per cent
8298	S. cen. sec. 35, Casselton Tp.	Brown loam, 0 to 14 inches	4.03	0.14	0.40	0.70	2.44	13.86	67.76	14.68
8422	Sec. 1, Harmony Tp.	Brown loose loam, 0 to 20 inches	4.69	.00	.90	.52	4.20	40.56	36.58	17.20
8425	Sec. 34, Everest Tp.	Brown loam, 0 to 15 inches	3.39	.30	.88	.78	1.88	30.90	34.54	30.54
8423	Subsoil of 8422	Gray loam, 20 to 36 inches	4.81	.00	.40	.50	1.78	34.60	39.26	23.30
8299	Subsoil of 8298	Gray clay loam, 14 to 36 inches	Tr.	.18	.16	.24	.86	7.92	64.56	25.80
8426	Subsoil of 8425	Loam, 15 to 36 inches	Tr.	Tr.	.62	.46	1.36	21.86	42.56	32.90

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8298, 3.53 per cent; No. 8299, 18.63 per cent; No. 8423, 8.01 per cent; No. 8426, 20.15 per cent.

MIAMI LOAM.

The Miami loam is composed of about 20 inches of heavy, rich dark-brown loam, somewhat similar in texture to the surface material

of the Miami black clay loam, grading without a perceptible change of texture into a grayish-yellow clay loam or clay. Below the third foot the soil retains the yellowish color, and sometimes becomes a trifle sandy. Iron oxides are often present in the lower depths and crystalline gypsum is frequently found in the second and third foot.

This type includes an area from 1½ to 2 miles wide, extending in a northeast-southwest direction along the eastern border of the distinct beach which passes through Wheatland. It is bordered on the east by the Miami black clay loam. The area covered by this type slopes gently toward the east, the inclination being sufficient to insure good drainage. This fact, together with the richness of the soil and its somewhat porous nature, makes it one of the most desirable types in the Red River Valley. It can be seeded or planted irrespective of wet weather, and the porous nature of the soil allows the moisture below to rise by capillarity in times of drought.

With the exception of a few spots, this type carries less than the minimum, 0.20 per cent, of alkali in the first 3 feet. The alkali content increases in the lower depths, but is not high enough to injure plants in any of the first 6 feet. The few spots where the injurious salts are found in excess are close to the sand beach forming the western boundary of the type, and seem to be due to saline springs which ooze out of the sand and gravel. With the exception of a narrow strip in secs. 3 and 10, Gill township, these areas were not large enough to be shown on a map of the scale used. They usually range from a few square rods to 2 acres in extent.

The typical areas of the soil are well adapted to wheat, oats, barley, corn, millet, and flax. During dry seasons the crops suffer to some extent from the effects of alkali.

The following table shows the texture of the soil and subsoil of this type:

MECHANICAL ANALYSES OF MIAMI LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8434	S. cen. sec. 6, Casselton Tp	Brown loam, 0 to 14 inches	6.75	3.50	7.84	4.74	18.76	25.86	26.60	12.66
8436	S. cen. sec. 13, Wheatland Tp	Brown loam, 0 to 15 inches	6.35	.00	2.80	5.50	21.00	19.96	29.92	20.86
8438	Middle of sec. 15, Gill Tp	Brown loam, 0 to 20 inches	5.56	Tr.	1.44	2.00	15.10	24.70	35.78	20.92
8135	Subsoil of 8434	Brown clay loam, 14 to 36 inches	1.42	7.30	9.18	4.38	13.68	18.68	22.20	24.06
8437	Subsoil of 8436	Clay loam, 15 to 36 inches	Tr.	1.00	2.80	2.60	9.30	9.40	25.48	48.80
8439	Subsoil of 8438	Yellow clay, 20 to 36 inches	.83	.00	.74	.72	5.18	12.48	25.90	54.76

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8435, 14.57 per cent; No. 8437, 8.81 per cent; No. 8439, 9.02 per cent.

MARSHALL GRAVELLY LOAM.

The Marshall gravelly loam is composed of about 12 inches of heavy black sandy loam, underlain by 2 feet of coarse gravel resting on a coarse sand extending to a depth of 6 feet or more. The most abundant rock constituent of the gravel is limestone. There are also present considerable quantities of granite and other crystalline rock fragments, and a few fragments of Cretaceous shale.

The type represents beaches formed during the recession of glacial Lake Agassiz. These beaches cross the area in fairly well defined lines in a northeast-southwest direction. In places they are broken down or obliterated, while in other places they appear like escarpments of glacial till modified by the action of water. In some places there are considerable quantities of large glacial bowlders strewn over the surface, but these are not numerous enough to seriously interfere with cultivation, and in most areas they have been gathered into piles. Where the railroads cut these beaches, large quantities of sand and gravel have been taken out for use along the tracks. The materials are also used throughout the country for building purposes.

Except in very wet seasons the crop yields on this type are very light, owing to the excessive drainage resulting from the gravelly nature of the subsoil. The areas occupied by this type are narrow, usually no more than 60 rods wide.

The following table gives the mechanical analyses of typical samples of fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL GRAVELLY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8446	SW. cor. sec. 6, Casselton Tp.	Brown, heavy, sandy loam, 0 to 14 inches	6.87	4.50	14.22	12.72	18.22	17.60	20.52	11.28
8449	N. cen. sec. 3, Gill Tp.	Brown, sandy loam, 0 to 14 inches	5.65	5.50	13.34	9.04	15.26	9.86	27.16	19.76
8447	Subsoil of 8446	Coarse gravel, 14 to 36 inches	.43	12.16	28.56	27.76	24.46	1.76	1.96	3.12
8450	Subsoil of 8449	Coarse gravel and sand, 14 to 36 inches	.74	6.00	16.46	13.76	48.66	4.98	4.70	5 34

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8447, 4.18 per cent; No. 8450, 5,14 per cent.

MARSHALL LOAM.

The soil of the Marshall loam consists of a dark-colored loam which grades into grayish-brown loam at about 8 inches below the surface. This is underlain by a gray silt or clay loam or clay containing some grit and reaching to a depth of 4 feet. Below the fourth foot the texture remains the same, but the color changes from grayish to yellowish. Below the second foot the materials are very similar to those occupying the corresponding section of Miami black clay loam.

This soil occupies the plateau area, extending in a northeast-southwest direction, in a body about 2 miles wide, across Wheatland and Gill township. It is bounded on the east by an ancient beach and on the west by the gently rising area occupied by the sandier type of soil, the Wheatland sand. Some of it is in a slight depression, but the porosity of the subsoil and the good natural drainage make it desirable for all farm crops. It is a little more subject to drought than the Miami loam. The chief distinctions between the Marshall loam and the Miami loam are that the latter has a deeper soil and is not so subject to drought. The crops yield a little better also, and altogether the Miami loam is recognized as the more desirable type. Along the western edge of the Marshall loam

area, where it comes in contact with the Wheatland sand, there are several patches of ground, usually not more than a few square rods or at most a few acres in extent, upon which oats, wheat, corn, flax, and other crops, after germinating and beginning an apparently healthy growth, are soon dwarfed and killed, while the closely adjoining crops present a healthy and vigorous appearance and on maturing give a satisfactory harvest. These spots are usually moist, and in dry weather a considerable crust of alkali can be seen. They are in the lower places, and where the underlying glacial till is only a short distance below the surface and are caused by the rise of the alkaline waters from the glacial till and the accumulation of the salts on the surface by evaporation. A field analysis of the soils in these spots shows that the chlorides predominate, but that considerable quantities of sulphates and some bicarbonates are also present.

This soil owes its origin partly to the transportation of fine sand from the higher lying Wheatland sand to the westward and partly to the overwash of the beach to the eastward during recession of the glacial lake. A little crystalline gypsum is found in some of the areas, usually not far beneath the surface, while at lower depths iron oxides are usually present.

The Marshall loam is recognized as a good, safe soil, regardless of wet or dry seasons. It is a better soil for all farm crops than any type in the area farther west, but the yields are not quite as large as on such types as the Miami loam and the Miami black clay loam, which have heavier subsoils. On the other hand, it is more easily worked. It is well adapted to wheat, oats, barley, corn, flax, Irish potatoes and truck crops.

The following table gives the mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MARSHALL LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8428	E. cen. sec. 4, Gill Tp....	Brown loam, 0 to 18 inches	4.70	0.52	1.70	2.04	11.24	26.96	39.16	17.88
8432	E. cen. sec. 17, Gill Tp...	Brown loam, 0 to 24 inches	5.29	.80	2.70	2.60	12.20	22.22	41.04	18.28
8430	N. cen. sec. 34, Wheatland Tp	Heavy loam, 18 to 36 inches.................	7.19	.90	3.70	4.30	13.84	16.70	37.60	22.96
8433	Subsoil of 8432............	Brown clay loam, 24 to 36 inches..................	5.14	.80	2.28	2.70	9.60	16.20	35.08	33.06
8429	Subsoil of 8428	Light clay loam, 18 to 36 inches.................	1.18	Tr.	.80	.84	5.00	21.70	36.52	34.80
8431	Subsoil of 8430............	Gray clay, 18 to 36 inches	1.01	1.10	1.92	1.92	4.90	6.86	42.70	40.60

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8429, 35.97 per cent; No. 8430, 1.02 per cent; No. 8431, 21.59 per cent; No. 8133, 7.39 per cent.

WHEATLAND SAND.

The Wheatland sand is composed of from twelve to eighteen inches of a medium fine dark-brown sand, which is underlain by grayish-yellow sand of the same texture to a depth of three feet. Below this depth the sand becomes coarser and yellower. At about six feet the material is often a clay loam of grayish-yellow color, containing a considerable quantity of iron oxides. The underlying glacial till is often reached in deep borings.

This soil occupies an area from three to four miles wide, extending across the area in a northeast-southwest direction through Wheatland, Gill and Howes townships. It is bounded on the west by the extreme eastern limit of the shore of glacial Lake Agassiz and on the east by areas of the Miami and the Marshall loams. From the eastern to the western edge of this area there is a rise of about 100 feet, so that, with the exception of two narrow strips along the old lake shore, extending across sections 11 and 14 in Howes township, the entire area is well drained. These two low, marshy places, which are a little below the natural avenues of drainage, are covered with water until late in the season, but furnish excellent pasture and hay meadows. In both of these marshes the soil and subsoil are of a more silty nature than in the rest of the type.

The Wheatland sand was formed by wave action, in shal ter, during the recession of the ancient lake. Throughout are several low beaches, often only a few feet high, and crests of these beaches the soil is usually too loose and san of value under the present conditions of agriculture. This the lightest soil in the Fargo area and needs much rain t fairly good crops. The crops are sometimes blown out b winds.

With the exception of some limited areas along the easter of this soil, it is freer from alkali than any of the other soi limited areas already mentioned are closely associated with t spots referred to in the description of the Marshall loam, confined to the lowest portions of sections 28, 32 and 33, W township. A field analysis of soil from these spots show they contain injurious quantities of both bicarbonates and c

In growing wheat this soil usually produces a good gr straw, but the plants do not head well and the yield is ligh well adapted to pasture and grazing.

The following table shows the texture of typical sample earth of this soil:

MECHANICAL ANALYSES OF WHEATLAND SAND

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1—mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent
8476	Sec. 17, Wheatland Tp.	Brown sandy loam, 0 to 8 inches	2.27	0.90	3.48	5.50	47.20	23.3
8478	Sec. 24, Howes Tp.	Sandy loam, 0 to 18 inches	2.55	.80	3.08	5.36	49.58	21.9
8477	Subsoil of 8476	Gravelly loam, 18 to 40 inches	.92	17.20	10.30	5.18	29.90	13.5
8479	Subsoil of 8478	Gravelly loam, 18 to 40 inches	1.50	12.90	9.56	5.46	23.38	15.4

The following samples contained more than one-half per cent of calcium ($CaCo_3$): No. 8177, 10.30 per cent; No. 8479, 7.93 per cent.

WHEATLAND SANDY LOAM.

The Wheatland sandy loam is composed of about fourtee of dark-brown sandy loam, underlain by a loam which at a six feet or more rests upon a grayish-yellow or yellow gla

Throughout the subsoil occur small rock fragments, varying from the size of a pea to that of an egg. In the second and third feet gypsum often occurs, and in lower depths concretions of iron oxide are usually present. Often the surface is strewn with gravel, especially on the crests of the prairie swells. Glacial bowlders of limestone, granite, gneiss and schist are abundant in places, though not usually in sufficient quantities to interfere with cultivation.

This type is found in the extreme western part of the area outside the limits of the territory once covered by Lake Agassiz. It extends westward past Buffalo, where the surface becomes more undulating. There is a gradual rise of about twenty feet to the mile toward the west, and the drainage is better than elsewhere in the area. In places there are many swales and kettle holes, with knolls and hills rising above them. Some of these places are filled with water the year round; others have a thick deposit of muck. None, however, were large enough to be shown in a map of the scale used, most of them being only an acre or two in extent.

No injurious amounts of alkali were found in either soil or subsoil to a depth of three feet, but several six-foot and nine-foot borings were made, and in these lower depths the alkali is sometimes found in considerable quantities. A few low spots contain so much alkali that nothing will grow, but these spots are usually not more than one or two rods across.

When the dry season is not too long the Wheatland sandy loam is a fairly desirable soil for general farming, as both soil and subsoil are of such a texture as to retain moisture well and to supply it to growing crops in time of drought. The soil varies according to location. On the crests of the prairie swells it is somewhat more sandy and gravelly than in the depressions, where the texture is decidedly more loamy. The soil in the lower places is regarded as more desirable when the season is not too wet.

This type is made up wholly of glacial till and is esteemed a stronger and safer soil than the Wheatland sand. But, like the latter, considerable of it is still unbroken and is used only for the production of wild hay and as pasture. This type produces fair crops of wheat, oats, flax, barley and corn. In the more loamy places it is found to be remarkably well adapted to Irish potatoes and other root crops.

The following table shows the texture of the fine earth of soil and subsoil as determined by mechanical analysis:

MECHANICAL ANALYSES OF WHEATLAND SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
8440	NE. cor. sec. 10, Buffalo Tp.	Brown sandy loam, 0 to 15 inches	6.31	2.50	4.40	4.10	17.52	19.46	35.16	16.96
8444	NE. cor. sec. 21, Howes Tp.	Brown sandy loam, 0 to 14 inches	6.98	1.50	4.46	4.94	19.00	20.74	28.88	20.4
8442	NE. cor. sec. 34, Buffalo Tp.	Brown sandy loam, 0 to 12 inches	4.87	1.20	4.16	4.66	6.50	20.38	30.70	22.00
8441	Subsoil of 8440	Yellow sandy loam, 15 to 36 inches	1.02	2.08	4.54	4.02	16.94	20.66	32.14	19.30
8445	Subsoil of 8444	Yellow loam, 14 to 26 inches	Tr.	2.24	5.10	5.76	20.18	19.18	19.78	27.00
8443	Subsoil of 8442	Yellow loam, 12 to 40 inches	1.54	2.50	6.10	5.30	15.98	18.68	22.50	28.40

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 8440, 2.17 per cent; No. 8441, 15.53 per cent; No. 8442, 4.35 per cent; No. 8443, 23.54 per cent No. 8444, 7.11 per cent; No. 8445, 22.68 per cent.

DRAINAGE.

The most important problem in the Red River valley and the one in which the farmers are taking the keenest interest, is the problem of drainage. Westward from the Red River to the Maple River, in a distance of fifteen miles there is only a difference of three feet in elevation. There are approximately 25,000 acres of land in this area upon which the water from the melting snow often does not run off or soak into the ground soon enough to permit seeding at the proper time in the spring. The subsoil is heavy, gummy, and impervious to water. This, together with the fact that the frost line is from five to eight feet below the surface, would make underdrainage very difficult, if not impossible. Some farmers "mud in" their crops; others are not able to do even this, the land being so soft that it is unsafe to put teams on it. "Mudding in" crops is very unsatisfactory, because after it is done the ground bakes so hard that a great deal of the seed never comes up, or is "choked off" after it does come up.

In seeding time after a copius rain all farm operations have to be postponed from a week to ten days, while the water gradually soaks

into the ground or slowly drains off. The seriousness of all this is more fully realized when one takes into account the shortness of the growing season in North Dakota, and also when one sees the disastrous effects of standing water upon growing crops. In the area under discussion, under the present imperfect conditions of drainage, it is only about one year in five that paying croys are harvested. It should be kept in mind that these wet areas, indicated on the soil map as the Fargo clay, are not altogether unproductive, but under favorable conditions produce the largest yields of grain of any soil type in the Red River valley. But the uncertainty of yield has led to the abandonment of these lands by most of the original owners. and at present it is often impossible even to find tenants willing to cultivate them. The few houses in this region are tumbling down, the yards are growing up to weeds, and the general appearance of things is in marked contrast with the prosperous appearance of the farms on the adjacent higher lying and better drained areas, indicated on the soil map as the Marshall clay. An unfortunate feature is that these lands are upon the market for speculative purposes and are quoted as high as the best lands adjoining. The unacquainted buyer who comes into the country with an honest intention of making it his home is often deceived, being led to believe that all Red River valley land is the same.

There are several causes for the present unfavorable condition of drainage in the Red River valley, the principal ones being the levelness of the country and the lack of fall in the Red River itself. It should be kept in mind, too, that the river flows north, and consequently the difference in time when the ice breaks up in its lower and its upper courses tends to hold the water back. Another thing which checks the flow of the stream is the crookedness of its channel. As a result, the river rises, backs up its tributaries and frequently the latter overflow their banks and flood the fields.

Obviously, man can not regulate the periods at which the ice breaks up in the lower and upper courses of the Red River, nor would it be practicable to attempt to deepen the channel; but enough remains to be done to greatly improve the present conditions, and the fertility and importance of the region to be benefited warrants the expenditure of a large sum of money. For example, where the channel is so crooked and meandering as to retard the river's flow,

it could be straightened so as to give the water a free course. Another important move in the control of the river, and one which has been under consideration for some time, is the construction of a storage reservoir in its upper course. During the spring freshets, and until after the ice had broken up along the international boundary line and beyond, this could be used to retain the water, which could then be let off gradually.

The most practical scheme, however, and the one which would be of immediate and probably of permanent relief, would be the construction of deep canals from the rivers to the undrained areas. In this matter the consideration of most vital importance is whether the fall between the undrained areas and the rivers is sufficient to carry off the water in case canals are constructed. From observations made during the survey and from an examination of the records of previous years' floods the conclusion is that such a scheme is entirely feasible. The main reason why drainage by this means has not been successfully established in the past is that it is too big an undertaking for private persons and needs state or national aid.

The record of the stages of the Red River at Fargo show that during the month of April the mean height of the river is approximately thirty feet below the level of the prairie. The undrained areas are from two to four miles west of the river, so that this would give a fall of from seven to ten feet per mile. It is believed that this is sufficient provided the canal were about twenty-five feet wide and fifteen feet deep. In this connection it might be well to state that the water table in this part of the Red River valley is about twenty-two feet below the surface, so that there is no danger of encountering it in a fifteen foot canal. Along the Sheyenne river, in the vicinity of Haggart, the conditions at first sight do not seem so favorable, because the mean height of the river during the month of April is only about eight feet below the level of the prairie, but as the undrained area east and west of the river is only from 1 to 2 miles off, this gives nearly as great an average fall per mile as in the area near the Red River. A canal dug from the Sheyenne at Haggart directly west for three miles to the large coulee would not only drain the wet area directly west of the river, but by deepening the coulee which goes southwest into Durbin township the large wet area in the vicinity of Durbin would also be drained.

The chief purpose of these canals would not be to carry off th water of spring freshets, but to furnish a ready outlet for the wate which accumulates in these low places after heavy rains. In th higher lying areas, indicated on the soil map as the Fargo clay there is a road along every section line and a ditch on each sid of the roads. After a heavy rain the water of these areas find a ready outlet through the ditches, and often this water accumu lates in the lower areas, converting them into sheets of wate and drowning out the crops. By the construction of canals th waters of the higher areas would be afforded a direct course t the rivers. Then by the construction of roads and ditches alon all the section lines of the low, wet areas the rain water woul have a free course through the ditches and canals into the river also. It has been demonstrated by the experiments on th college farm at Fargo that the first requisite in reclaiming the low wet lands is drainage, and that then by deep plowing and carefu methods of cultivation the "gumbo" properties of this soil graduall disappear.

ALKALI IN SOILS.

All the soils of the area contain some alkali either in the soil, th subsoil, or in still lower depths. The "gumbo" areas and an are of low, sandy country west of Wheatland, occupied by the Wheatland sand and the Marshall loam, are the only areas which contai injurious amounts of alkali in the first three feet.

It was found that in the "gumbo" or Fargo clay areas the surfac foot was comparatively free from alkali, while in the sandy area referred to above, the injurious alkali was either upon or near the surface. This was found to be due to the fact that in the case of "gumbo" there is no percolation upward of soil moisture because the soil is too impervious, and hence there could be no concentration near the surface by evaporation. In dry weather the surface of the heavy soil bakes and cracks up into irregular pieces. In the case of the sandy area the water table is only from six to fifteen feet below the surface; sufficiently near for capillary forces to bring the underground water to the surface. The worst alkali conditions were found where the water table was nearest the surface and where the soil was also sandy and porous. Wells in this vicinity are commonly so alkaline that the water can not be used for drinking purposes.

Fair crops were seen growing upon the Fargo clay when the average for the first three feet was as high as .35 per cent alkali, but with the greater amounts in the second and third feet, while in the sandy area west of Wheatland the grain was killed when the average for the first three feet was only .20 per cent alkali, but with a concentration in the first two or three inches.

Injury from alkali is very largely a matter of seasons. If it happens to be wet at seeding time and continues so until the crops get a good start there is apparently no injury. On the same piece of ground the crops may be entirely killed the next year if the soil is very dry at seeding time and the alkali is concentrated near the surface.

In the case of the Marshall clay the alkali content gradually increased downward to six feet, with apparently no concentration in any particular foot section, while in the case of the sandy soils west of Wheatland the alkali content decreased until there was often almost none at nine feet. No borings were made deeper than nine feet. In the higher lying areas of the Wheatland sand, where the water table was far below the surface, the soil was often free from alkali, and only a very little was found in the lower depths of the subsoil. In all other types in the area the alkali content invariably increased in the deeper subsoil.

There seems to be no relation between the proportion of alkali in the soils and in the water of wells, except when the soils are very porous, as in the case of Wheatland sand, and the water table is only a few feet below the surface.

Along the foot of the old beach which passes through Wheatland there are several small spots which are so badly alkaline that the crops usually "burn out." Only one of these spots was large enough to map on the scale used. These spots are the result of the seepage

Under the present methods of farming, where land is so plentiful and where everything is done on such a large scale, the alkali will never be a serious problem. Nothing has ever been done to remove
from alkali springs at the bottom of the old beach.
it, and very little is said or thought about it. The all-important question over most of the area, and the question which is being seriously considered, is how to drain the low, flat lands in the vicinity of the Sheyenne and Red rivers.

AGRICULTURAL METHODS.

The early settlers of the Red River Valley were surrounded by conditions very different from those in almost any other part of the country. There were no rocks to be removed and no forests to be cleared. The settler had simply to build his sod house and barn, turn up the rich, level prairie soil, and sow his seed.

When the special adaptation of the valley for wheat became known the region leaped into prosperity, and the land values—a few dollars an acre a generation ago—have steadily increased to an average of $35 an acre at the present time. No other portion of the country could compete in wheat production with this region, because of the cheapness with which this crop could be produced and the vast scale upon which it was grown. The gradual extension of the wheat-growing region to other portions of the northwest and the lower Canadian provinces has made the supply greater and the prices lower. The continual growing of wheat for twenty years has in most places decreased the yield from the soil about one-half. These conditions are forcing the farmers of the region to adopt better methods.

Since its introduction flax has been one of the most profitable crops in the area, and especially so upon new land. It has been so profitable that farmers have been known to pay for their farms with profits from two crops. During the past few years, however, the crop has been seriously affected by a fungous disease popularly known as "flax wilt." The disease has been studied at the experiment station at Fargo, and the experiments, together with a study of the conditions in other flax-growing countries, show that the plant can not be profitably produced year after year upon the same land.

The spread of the disease to new lands can be avoided by the selection of healthy seed and by the treatment of all seed with a solution of formaldehyde. As yet no method has been found to do away with the fungi after the soil has been infected. In Russia and Belgium, where the plant is extensively grown, a period of from seven to twelve years is necessary between the crops if this disease is to be avoided. Crops in closer succession become wholly worthless on account of the disease.

A considerable revenue is now obtained from the sale of flax straw, where formerly it was burned after threshing. The farmers haul the straw to the mill at Amenia, or at Fargo, where it brings

$2 a ton. It is drawn to market in the winter when the roads are hard and at a time when farmers have little else to do. The mills dispose of their product in the east, where it is used largely in the manufacture of paper.

During the last two or three years macaroni wheat has been grown to some extent; and, although the price is lower than that for the standard varieties grown in the area, the fact that the yield is about one-third larger is making the variety popular.

On the loamy types of soil where the drainage conditions are favorable Irish potatoes do remarkably well, sometimes yielding as high as 200 bushels per acre. As yet they are grown only to supply local markets, though a few shipments have been made to southern states for use as seed.

The climate and soil is well fitted to the production of nearly all kinds of late vegetables. Celery does very well, and, judging from a few sugar beets grown in gardens, it would seem that there is a good opportunity for the introduction of that industry.

Strawberries, gooseberries, raspberries, and currants, provided they are sheltered from the winds by hedges of golden Russian willow, Norway spruce, soft maple, poplar, or in fact any kind of tree that will endure the climate, can be profitably produced. There is no one thing which is needed more or which would be of more value to the area than trees. Along the Sheyenne river in the vicinity of Haggart, where there are many large native trees, the weather in winter is much milder. In the midst of these trees a few apples and plums are being successfully grown, largely because the young trees are protected from the cold winds and the blossoms are not blown off in the spring.

Corn has been introduced and acclimated to the short growing season, and is now one of the important crops of the area. It is usually rotated with wheat, the latter producing greater yields and being freer from weeds if sown after the cultivated crop of corn.

Throughout the area there is a general lack of care in plowing and in preparing the seed bed. Plowing is usually very shallow, and this has decreased the productiveness of the soil. The practice of plowing a little deeper every third or fourth year and bring up an inch or so of the new soil to the surface to be acted upon by the weather and soil bacteria, is the most satisfactory method. It is best to plow in the fall and harrow immediately, so as to fill up the large air spaces and prevent the furrow splice from drying out. If

this is done, the soil will settle down sufficiently during the winter and spring months to establish good capillary connection with the subsoil.

No commercial fertilizer has ever been used in the area, and heretofore the opinion has prevailed that barnyard manure was more injurious than beneficial to crops. Where coarse manures are turned under they often have a tendency to make the soil too dry. When well-rotted manures were turned under they often had a tendency to make the growth of straw so large that it would lodge before harvesting. During the last few years, however, it is found that crops are greatly benefited if well-rotted manure is spread on the plowed ground in the fall and allowed to remain there all winter. It is often advisable to rake up and burn the coarse litter in the spring at seeding time. A great deal of manure in the area is still wasted, as formerly, by being dumped into the sloughs or drawn out in piles and burned.

AGRICULTURAL CONDITIONS.

The chief resources of the area are found in its very productive soil, especially as adapted to the production of grain. On the better types of soil and where the farmers have paid attention to business most of them have become independently wealthy. In most cases they came into the country when it was new and either acquired their lands from the government as homesteads or purchased them cheaply from other settlers who had thus obtained them. A large part of their present wealth, therefore, has not been made off the land itself, but on the natural increase of land values, which have steadily increased from a few dollars to about $35 an acre at the present time, with a probability of still higher value in the future.

A very few of the farms are owned by persons who spend no part of the year in North Dakota, but leave their property in the hands of agents for speculative purposes or rent them for cash or on shares to farming tenants.

Most of the farms originally contained 160 acres, although a few were as large as 480 acres. The large farms were generally acquired by purchasing from railroad corporations the odd numbered alternate sections given to them by the government as a subsidy to foster their early enterprise. In order to form a compact tract the intervening portions were often purchased from settlers, so that at present the size of holdings ranges from eighty to 20,000 acres. The

two largest holdings in the county are one at Casselton, containing 13,000 acres and another at Amenia, containing 20,000 acres. The former is operated as a single farm, while the latter is owned by a company and leased on shares to tenants, no single tenant being permitted to work more than one section. In the vicinity of Fargo and Casselton the farms are larger than around Wheatland, and the average size of the farms throughout this area is about 600 acres.

As a rule the present land values of the area are on a legitimate basis. In a few localities where the drainage is very imperfect the land values are a little higher than the present conditions would seem to warrant, but on the whole there is bound to be a healthy increase upon the present basis. Some of the best farms are mortgaged, but these mortgages are held by local investors. In this portion of the northwest farm mortgages indicate prosperity rather than adversity. The farms that a score or more years ago were too large for the poor farmer with his large family of small children are now too small for the grown-up boys. The family spreads and the boys marry and buy adjoining farms. The father gives them a start with a few hundred dollars, to which they add their own savings. A part is paid down for the farm and a mortgage is given for the remainder and in the majority of cases with care and industry it is only a few years before the boys have clear titles to their farms.

The question of labor is one that is continually causing dissatisfaction among those who are operating large farms. One reason is that the poor man of enterprise and push will not remain a day laborer long because of the opportunity of his getting land and starting a home of his own. Men with enough money to make a small payment and sufficient stock and machinery to start work have been known to pay for a half section of land in two years. At the present time men of no money or stock and machinery, but with a reputation for honesty and industry, usually have no trouble in obtaining a farm with buildings, stock and machinery, and are given plenty of time in which to pay for them. The usual method is by "crop payments," giving one-half the crop each year until the indebtedness is canceled. Upon such terms with ordinary seasons and industry a man with one or two boys old enough to work can get clear title to a half section in less than ten years, provided the farm is located upon such types as the Miami black clay loam or the Miami

loam. By a process of natural selection these conditions have left as laborers a class of unmarried men who are usually rather undesirable. In the winter they divide their time between the great cities and the lumber camps of the middle west; in seeding and harvest time they migrate to the grain-growing communities and demand exorbitant wages. The farmer who has to hire is at their mercy and must pay at least $2.50 a day for common labor, besides furnishing board and lodging. It is often impossible to obtain help at $3 a day. Upon the whole, the present dissatisfaction with labor is having a salutary effect upon the country and matters are gradually adjusting themselves. Farming on a large scale is declining, because of the lower prices for grain, the inefficiency of labor and the high wages demanded by it. The large farms are being cut up to furnish homes for the many, farming is becoming more diversified and better methods of cultivation are being introduced.

Wheat, flax, barley and oats have been and are the chief products of the region. The heavy loamy and clay soils of the valley are recognized as being especially adapted to these crops and the seasons are favorable. Formerly it was believed that the seasons were too short for corn, but a variety has been acclimated to the region and now thousands of acres of it are grown yearly. Corn and barley are being grown more and more every year, and hogs are being raised. This is an industry which is becoming important. Last year many carloads of hogs were shipped out of the Red River valley to the Minneapolis, St. Paul and Chicago markets.

The transportation facilities of the area are very good, the main line of the Northern Pacific passing through its entire length from east to west. A branch of this road, known as the Fargo & Southwestern, runs from Fargo to Lisbon, crossing the southeastern part of the area. The main line of the Great Northern crosses the area at Fargo and a branch of that line crosses at Casselton. Along these roads at intervals of about five miles are sidetracks with platforms and at many of these shipping points there are elevators for storing grain. Many farmers load their grain directly into cars from the platforms, while some store it in the elevators to await future shipment.

SOIL SURVEY OF JAMESTOWN AREA.

BY THOMAS A. CAINE AND A. E. KOCHER.

(Field operations, bureau of soils, 1903.)

LOCATION AND BOUNDARIES OF THE AREA.

The Jamestown area is located in the east central part of North Dakota and comprises parts of Stutsman and Barnes counties. It is included within meridians 98 degrees and 98 degrees, 53 minutes and 34 seconds west longitude and 46 degrees, 48 minutes and 15 seconds and 46 degrees, 58 minutes and 41 seconds north latitude and is made up of townships 139 and 140 north, ranges 58 to 65, inclusive, west.

The area has an extent of approximately 496 square miles, or 317,760 acres.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The experiences of the early settlers of the area were similar to those of all the early settlers of the northwest. The earlier permanent settlements were made in 1871, after the Northern Pacific railroad had penetrated the region. In 1872 the city of Jamestown was founded by the railroad company. Stutsman county was organized in 1872 under the laws of Dakota territory. The first actual settlements in Barnes county were not made until 1877 and the following year the county was organized with Valley City as the county seat. Prior to 1880 the growth of the town was slow, on account of the embarrassment of the railroad and because of other drawbacks which retarded the settlement of the surrounding country. The very earliest settlements were scattered and for the most part of a transient nature. The long, rigorous winters, the lack of fuel and the blizzards of the early days were hardships hardly appreciated by those now living under the modified conditions of climate with better facilities for obtaining fuel. But from the beginning the growth of the region has been a healthy and vigorous one. The sturdy, industrious class of farmers who came from Scandinavia have done much to bring the region into prominence.

In 1887 a general immigration set into the territory as a whole and the location and productiveness of the area surveyed attracted its full share of newcomers. In 1889 the states of North and South Dakota were created out of Dakota territory. From 1880 to the present time the history of the region has been one of growth and

prosperity. The lands which were either taken up under the homestead act or purchased from the railroad corporations for a nominal sum, have steadily increased in value, and during the past few years have doubled and in some cases trebled in value. In the eastern part of the area the present average price per acre is $25. In the vicinity of Jamestown the average price for the prairie soil is about one-third lower than at Valley City.

CLIMATE.

Owing to the absence of forests and the geographic position of the area, in the center of a large continent, and about equidistant between the north pole and the equator, the difference between the temperature of summer and that of winter is very great. Usually there are only a few days in summer when the mercury gets as high as 100 degrees F., and the nights are always cool. The seasons are sharply separated. Spring comes by a sudden transition in April, when the surface of the ground thaws rapidly, permitting seeding in a few days. Winter comes on by a sudden cold wave in November, when the ground freezes and stops the fall plowing.

During the months of January and February the temperature is often from 10 degrees to 30 degrees below zero for days at a time, but the dryness of the atmosphere makes this low temperature no more difficult to endure than a much higher temperature along the coast or lakes, where the atmosphere is damp.

There is a considerable difference in precipitation between the extreme eastern and the extreme western limits of the area. The records of the weather bureau station at Jamestown cover a period of twelve years and show that the average yearly precipitation is about eighteen inches. The year 1899 was an exceptional year, when the precipitation was as low as 6.75 inches. In 1896 the total rainfall was also exceptional, when it reached 33.09 inches. Although the records at Valley City are incomplete, it is pretty well established that the average yearly precipitation is about twenty-one inches. The chain of lakes in the vicinity of Sanborn seem to affect the conditions of precipitation, for east of these lakes the precipitation is practically the same as at Valley City, while west of them it is about the same as at Jamestown. The subsoils east of the lakes are a trifle heavier and therefore better able to retain moisture. These are facts well recognized by the farmers and all lands east of the lake chains are held at from $5 to $10 more an acre than those to the westward.

The presence of so many native trees along the Sheyenne River is also believed to have something to do with the greater precipitation.

The following table gives the normal temperature and precipitation, so far as available, from the records of the weather bureau stations at Jamestown and Steele:

NORMAL MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Jamestown		Steele		Month	Jamestown		Steele	
	Temperature—degrees F.	Precipitation—inches	Temperature—degrees F.	Precipitation—inches		Temperature—degrees F.	Precipitation—inches	Temperature—degrees F.	Precipitation—inches
January	9.0	0.53	8.0	0.52	August	67.0	1.28	66.0	2.20
February	9.0	.56	7.0	.36	September	58.0	.93	58.0	.76
March	19.0	1.00	15.0	.66	October	46.0	.53	41.0	.39
April	42.0	2.21	41.0	1.65	November	22.0	1.15	25.0	.59
May	53.0	2.98	54.0	2.44	December	16.0	.74	14.0	.24
June	65.0	4.21	63.0	3.42					
July	70.0	......	68.0	2.76	Year	39.7	......	38.3	15.79

The winters are less severe than formerly, the greatest change being in the months of January and February. In these months there has been a decided increase in temperature and a slight increase in the months of March, April and May, while during the remainder of the year the conditions have been more constant. That the winters are milder now than formerly is a fact well recognized by all farmers who have lived in the valley for a score or more of years.

Owing to the difficulty of getting onto the fields early enough in spring to plow for seeding, nearly all plowing is done in the fall after harvest, thus exposing the characteristic black soil of the region to the sun during the winter months, while in the summer months the growing and maturing crops represent more nearly the original prairie condition. This is doubtless one reason why there has not been so great an increase of temperature during the summer as in the months of January and February. The rainfall is greatest during the months when it is needed most by the growing crops, namely, in June and July. During January and February the average precipitation is less than one inch. The small amount of snow that falls during these months is not lodged in the prairie grass as formerly, but is either blown off the plowed fields into the coulees or is melted upon the heat-absorbing black soil during the bright days. Before the country was broken up the snow was held in the

prairie grass, the light-colored grass and lighter-colored snow tending rather to reflect the sun's rays than to absorb them. The conclusion is that the change of temperature is due to the exposure of so much black soil to the sun during the winter months.

On the whole, the length of the growing season seems to be a little longer and therefore the conditions are getting more favorable for corn. This change may be ascribed to the same cause as the milder winters—the exposure of the black soil to the sun. While it is well known that a black soil radiates heat as rapidly at night as it absorbs it during the day, it should be remembered that in this northern latitude during the spring, summer and fall there are more hours of sunshine per day than in latitudes farther south.

The term "killing frost" represents a frost which will kill such crops as are generally grown in the valley and usually represents a temperature of 24 degrees F. If fruits were grown in the valley a much higher temperature would doubtless be regarded as a killing frost.

The records for the past several years show the average dates of the last killing frost in spring and the first in fall to be as follows:

	Last in spring	First in fall
Jamestown	June 1	Sept. 12
Steele	May 27	Sept. 13

PHYSIOGRAPHY AND GEOLOGY.

The entire area was covered with ice during the glacial period. One can form a better idea of this period if he thinks of a great mass of ice flowing or shoving its way across the country from north to south, carrying with it large quantities of granite, gneiss, schist and limestone from Canada, planing off the hills and filling the valleys with the material of the hills. This was not a condition peculiar to North Dakota, but common to the northern states from North Dakota to Maine. When this great mass of ice retreated or thawed away, the ground-up rock fragments which had been carried along by it were left as a mantle over the glaciated region. The thickness of this mantle of glacial till, as it is commonly called, varies in different parts of the glaciated region, but in the area surveyed the average thickness is less than 100 feet.

The topography of glaciated regions varies from comparatively level to hilly and broken. With the exception of the morainic hills south of Sanborn the surface in this area may be classed as level prairie. It is characterized by its gently undulating surface, made up of a succession of low hills and knolls and shallow depressions, with a few glacial bowlders and some gravel strewn upon the surface and disseminated through both soil and subsoil.

From the extreme eastern to the extreme western limits of the area, a distance of forty-two miles, there is a gradual rise westward of about 125 feet. This gradually rising and gently undulating prairie is broken by two deep gorges, where the James and Sheyenne rivers have cut their channels. The waters of the former stream eventually reach the Gulf of Mexico, while those of the latter flow into Hudson Bay. The divide between these two systems of drainage crosses the area at Eckelson. Jamestown, on the James River, has an altitude of 1,400 feet and is 115 feet below the top of the prairie, while Valley City, on the Sheyenne, has an altitude of 1,221 feet and is over 200 feet below the prairie. The lowest point in the area is 1,200 feet above sea level, while the highest point is on the terminal moraine south of Sanborn and has an altitude of 1,600 feet, so that there is a range in elevation of 400 feet in the area.

The James and the Sheyenne rivers are now small and sluggish, and it was during the glacial period, when they were swollen with the waters of the melting ice, that their deep gorges were cut. The bluffs along the James are made up entirely of glacial till, the underlying Cretaceous rock of the county being exposed only in the lower places along the stream. These bluffs are characterized by their serrated appearance and also by the fact that their steep sides are strewn with glacial bowlders of all sorts and sizes. The bluffs along the Sheyenne river have an entirely different appearance. Their tops are capped by only a thin mantle of glacial till. The line of separation between this till and the underlying Cretaceous shales can be traced by the difference in vegetation above and below the line. Above the line the bluffs have the appearance of those along the James, being serrated and covered with glacial bowlders, and because of the slight rainfall and extreme conditions of drainage, devoid of all vegetation except a scanty growth of grass. Below the line the numerous springs which come out on top of the

Cretaceous shales furnish sufficient moisture for a natural vegetation of oak and other hardwood trees.

Between the James and the Sheyenne rivers are several dry waterways which cross the area in a north and south direction. None of these waterways are more than 40 feet deep. They are fairly well defined and doubtless served as avenues for carrying off a great deal of water from melting ice to the northward during the glacial period. Some of these old water courses are cut into the underlying Cretaceous rock, and they may represent preglacial channels that were not so completely filled with glacial material during glacial times but that they still served to carry off the water from melting ice. Water has not flowed through these valleys within the memory of man, and they are now entirely dry, except in the depressions which are considerably below the natural avenue of drainage. Water usually collects in these depressions, and often a series of lakes may be traced along these old water courses. Such a chain consists of Fox, Rose, Goose and Mud lakes.

The lakes mentioned above have no outlets and their waters contain a great deal of alkali. Goose and Mud lakes are very shallow and often become dry by evaporation in the summer. The alkali, which was in solution, is then left as a white deposit along the shores and dry bottoms of these lakes, but when the wet season returns these salts are again taken up. If the waters of these two lakes were drained off and the salt not allowed to accumulate, their mud bottoms would probably become valuable for the production of hay.

A characteristic of all these lakes is that they have a distinct fringe of sand, gravel and bowlders along their shores. This was such a distinct feature and so much ground was covered with shore bowlder-chains that it was indicated as a distinct type in the soil map. Its origin can be traced to the sand, gravel and waterworn rocks and pebbles strewn along old water courses. The sand and gravel along the lakes are composed of this material sorted by wave action of existing lakes, but the long line of accompanying bowlders is acounted for by a different phenomenon. During the intensely cold winters these shallow lakes freeze to their bottoms. The rocks and bowlders in the bottom are frozen into the ice. Large cracks appear in the ice and during the warmer days these cracks are filled with water, which freezes and expands. The result is a pushing of

the ice upon the shores and the carrying of the rocks a little farther shoreward with each successive winter. The finer material along the bottom is also frozen into the ice, and when the ice breaks up in the spring it is carried along in the direction of the prevailing wind. The sand and gravel thus accumulated are reworked by the waves and piled up by them, forming beaches.

SOILS.

The location of the area about midmay between the lands used exclusively for grazing and those used for grain growing makes it representative of the types of soil and the conditions of climate over a very large and important part of the state.

The following chapters give a description of the soil types met with in the area and the appended tables shows the extent of each of these types and the proportion which each bears to the total area.

AREAS OF DIFFERENT SOILS

Soil	Acres	Per cent	Soil	Acres	Per cent
Marshall loam............	206,976	65.1	Meadow.................	4,992	1.5
Marshall silt loam........	41,280	13.2	Hobart clay.............	3,712	1.1
Marshall stony loam......	30,208	9.5	Sioux clay..............	2,432	.8
Riverwash...............	17,408	5.5			
Sioux fine sandy loam....	5,632	1.7	Total.................	317,760	....
Miami black clay loam...	5,120	1.5			

MARSHALL STONY LOAM.

The Marshall stony loam has an average depth of about seven inches of drak-brown, loose, sandy or gravelly loam. Occasionally there is present an admixture of considerable clay loam, and again the interstitial material may be almost wholly coarse sand. The surface soil is underlain to a great depth by unmodified glacial till Disseminated throughout both soil and subsoil and scattered in large quantities on the surface, are glacial bowlders of all sorts and sizes. This type is in nearly all cases associated with the abandoned waterways and with the moraines which are scattered over the entire area but are especially numerous south of Sanborn. It also occurs as narrow areas encircling Miami black clay loam. Here the soil represents beaches of old lakes or ponds.

This type is also found on the sides of all the serrated bluffs of the James river and on the sides of the deep coulees which lead into this river. Along the Sheyenne in the vicinity of Valley City and to the southward this type is found only on the tops of the bluffs,

the lower part of the bluffs being composed of the Cretaceous shales. On the river northwest of the town the glacial till has been spread as a mantle over the entire bluffs from top to bottom and in such locations the conditions are the same as those on the sides of the bluffs of the James river.

The moraines represent places where the edge of the melting ice sheet stood for some time. The character of the material thus accumulated varies. Sometimes it is quite sandy, nearly always it is very stony, while occasionally it is very nearly the same in texture and appearance as the Marshall loam found on the level prairie, but because of the slight rainfall, and owing to its elevated position or its great porosity, it is too dry to be of any great agricultural value except as pasture.

South of Sanborn some of the morainic hills mapped as this type rise to an elevation of 200 feet above the surrounding prairie. The subsoil in some of these hills is not unlike the soil on the level prairie, but the soil on their steep slopes has been so washed that nothing but the coarser constituents are left, the finer particles having been carried down into the valleys between the hills. Occasionally fair crops are grown about half way up the sides of some of these hills, depending upon the season and the local conditions of moisture, but considerable areas are of no value except as pasture lands.

A phase of the Marshall stony loam consists of a dark-brown or black loam, with an average depth of twenty inches, underlain by a subsoil of coarse sand or gravel. As in the type riverwash the subsoil often persists to a great depth. Disseminated throughout the soil and subsoil are large glacial bowlders. In the soil there is usually present considerable organic matter derived from the luxuriant grasses which grow in such locations. In the lower depth of the subsoil, at about fifteen feet below the surface, there is often one or two inches of bluish-gray silt or clay.

This phase is found in the bottoms of the "dry waterways" which were avenues for the water from melting ice in glacial times. It differs from the riverwash chiefly in that the latter is found in higher locations and is dry throughout the year and therefore of little agricultural value except as a scanty pasture. It differs from the areas mapped as meadow in that the latter are too low and marshy to be of much agricultural value under present conditions.

In all cases the surface soil of this phase is a wash of the finer sands and silts from the higher surrounding prairie and is a veneering over the wash left at the close of the glacial period. In a few locations the lowest slopes of the typical Marshall stony loam have been veneered over by a wash from higher grounds. As in the case of the typical stony loam, there are sometimes numerous large bowlders protruding above the surface.

This phase of the Marshall stony loam, occupying as it does the lower, but not the lowest parts of the old water courses, usually contains plenty of moisture during the greater part of the year. In times of excessive rain, however, it is usually very wet and occasionally flooded, while during the long-continued drought it may become very dry because of the loose, porous nature of the subsoil. Because of this and because in some locations there are injurious amounts of alkali, it is not a desirable soil for cultivated crops. The type seems usually well adapted to grains and pasture and is used almost exclusively for these purposes. It would doubtless be better if no attempt were ever made to put this type under cultivation. It is now one of the most valuable types in the area for grass, and since so much of the prairie has been broken and the prairie grass destroyed there is an increasing demand for hay.

The following table shows the texture of samples of the fine earth of the Marshall stony loam:

MECHANICAL ANALYSES OF MARSHALL STONY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9159	4½ miles SW. of Eckelson	Brown loam, 0 to 8 inches	5.27	3.82	8.22	8.16	23.56	20.42	28.42	7.38
9161	Valley City	Brown stony loam, 0 to 30 inches	10.57	3.18	5.68	4.98	20.90	21.80	36.04	7.42
9162	Jamestown	Loam, 0 to 6 inches	7.12	4.12	7.42	7.00	20.82	15.42	34.54	10.50
9158	2½ miles S. of Eckelson	Brown gravelly loam, 0 to 8 inches	3.93	2.28	8.70	10.42	28.66	15.08	22.78	12.06
9160	Subsoil of 9159	Light brown loam 8 to 30 inches	3.60	3.10	7.82	7.12	20.36	17.56	29.88	13.94
9163	Subsoil of 9162	Sandy loam, 6 to 40 inches	2.39	3.92	7.20	7.38	20.38	12.76	28.52	19.74

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9158, 15.20 per cent; No. 9160, 1.62 per cent; No. 9161, 6.30 per cent; No. 9163, 4.60 per cent.

MARSHALL SILT LOAM.

The surface soil of the Marshall silt loam consists of a dark-brown to black loam with an average depth of ten or twelve inches. The subsoil is slightly more silty and clayey in texture and varies in color from dark brown to brown, usually becoming yellowish brown in the lower depths.

Scattered upon the surface and disseminated through both soil and subsoil, are fragments of rock varing in size from fine gravel to large glacial bowlders. These, however, are not so numerous as in the case of the Marshall loam.

This type is typically developed on the level prairie about 200 feet above the Sheyenne river, in the vicinity of Valley City and in its most typical phase extends back from one and a half to three miles on each side of the bluffs. These narrow strips represent the flood plain of the river in glacial times. In its least typical phase the soil extends several miles back from the river, but only a small part of the region east of the river was included within the area. It reaches west as far as Sanborn and Hobart lakes and to the foot of the morainic hills immediately south of these lakes. The dividing line between this type and the Marshall loam leaves the area about two miles northwest of Sanborn.

In its topographic features it is much more level than the Marshall loam and in the narrow strip on each side of the Sheyenne river it has been considerably cut up by ravines and coulees, but the outline of the original level can be traced for miles. Back from the river some distance its topography becomes gently undulating and is marked by a succession of low hills and shallow depressions locally known as "bog holes."

The origin of this type is glacial, as in the case of the Marshall loam, but it differs from the latter in that the underlying Cretaceous rock is in some cases very close to the surface and has entered very largely into the composition of the soil. This accounts for its being heavier in texture than the Marshall loam.

This type retains moisture better than the Marshall loam.

For general farming purposes this soil has no equal in the area. It is all under cultivation and is held at about $30 an acre. Thirty-five bushels of wheat is not an unusual average yield. Flax, oats and barley do comparatively well.

In some places in this type there are occasional small patches on which the grain becomes partially choked off, an effect due to the gumbo characteristic of the soil. These areas are not large enough to interfere seriously with the value of this type.

The following table shows the texture of typical samples of the fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL SILT LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9167	2 miles E. of Sanborn..	Loam, 0 to 8 inches	7.58	2.06	8.32	8.18	27.56	15.90	31.06	6.84
9165	4 miles E. of Hobart ...	Gray silty loam, 0 to 12 inches	3.44	.12	.76	1.32	5.36	6.42	71.42	11.00
9168	Subsoil of 9167	Loam, 8 to 40 inches	4.04	2.86	10.80	10.24	30.08	13.16	24.56	8.22
9166	Subsoil of 9165	Yellow silty loam, 12 to 40 inches..............	3.15	.10	.32	.30	1.32	2.50	80.00	15.18

The following samples contained more than one-half per cent of calcium carbonate ($CaCo_3$); No. 9166, 14.15 per cent; No. 9168, 0.60 per cent.

SIOUX CLAY.

The soil of the Sioux clay is a black to dark-brown or sometimes yellowish-brown, clay loam or clay, with an average depth of eighteen inches. The subsoil is a grayish-brown to grayish-yellow, stiff, waxy clay loam or clay, with a depth of several feet. The difference between the soil and subsoil is that the former has more organic matter incorporated with it and is a little more sandy.

The Sioux clay is a type confined to the bottoms of the Sheyenne river, from the vicinity of Valley City southward to beyond the southern limits of the area. The soil is partly of alluvial origin and partly a wash from the Cretaceous bluffs which rise about 150 feet on each side of the river. The residual soil formed from the weathering of the soft shale in these Cretaceous bluffs has all of the characteristics of the gumbo found in the Red River valley. It is exceeding slippery under foot, is very waxy and gummy and has a greasy, oily feel. The Red River valley gumbo is doubtless the same material carried in suspension by the glacial waters and redeposited in glacial Lake Agassiz. But there are no large bodies of this residual soil, since in its redeposition along the river it has all been

more or less intimately mixed with a small amount of fine sand that has found its way down from the higher prairie. In some places the type varies from a fine friable loam to a stiff silty clay, having the objectionable features of gumbo.

This type, with the exception of a few gumbo spots which bake and dry out during a dry summer, is excellent for truck farming as well as for the growing of small grain. Under the best of conditions wheat sometimes yields as much as forty bushels per acre upon this soil. Oats and flax also do remarkably well. Only about one-half of this type is under cultivation, the remainder being occupied by a growth of oak, elm, ash and other indigenous trees.

Where cultivated this type is used largely for growing small grain and millet. The shelter afforded by the trees would make it one of the most desirable locations in the state for growing orchard fruit and berries.

The following table shows the texture of typical samples of this soil:

MECHAICAL ANALYSES OF SIOUX CLAY

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9176	Valley City	Brown loam, 0 to 36 inches	0.67	0.01	0.16	0.28	3.52	10.92	58.66	25.88
9174	5 miles S. of Valley City	Clay loam, 0 to 12 inches	5.23	.00	.30	.82	5.66	4.52	32.06	6.64
9175	Subsoil of 9174	Clay loam, 12 to 40 inches	.19	.06	.56	1.90	8.92	5.30	30.80	52.34

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9174, 4.55 per cent; No. 9175, 14.10 per cent; No. 9176, 8.20 per cent.

HOBART CLAY.

The Hobart clay consists of from one inch to four inches of a gray or dark-brown clay, underlain to a depth of three or four feet by heavy drab-colored clay. In the lower depth of the subsoil the clay is more or less intimately mixed with fragments of the underlying Cretaceous shale. Below the fourth foot the shale is found in various stages of disintegration, until finally the solid rock is reached. The harder parts in the shale or such parts as are more resistant to the agencies of weathering are frequently seen strewn upon

the surface. This accounts for the presence of small fragments of gypsum, "iron" shale and calcareous and fossiliferous shale. When the soil is wet it is very adhesive and slippery under foot and has a greasy, oily feel. In dry weather it often bakes and growing crops are often injured in this way. In a few places along the steepest bluffs the shale has not weathered sufficiently to support any vegetation, and at such places small landslides frequently occur. In places such landslides have carried down the glacial till from above.

A peculiar feature of this type, and one which is not common on any other type in the area, is the occurrence of numerous fresh-water springs, formed by the water soaking down through the porous soils resting as a mantle upon the Cretaceous shales until the impervious clay and shale are reached, when it flows laterally and issues from the sides of the hills.

Owing to the stiff, tenacious character of the soil and its location upon the steep sides of the bluffs, this type has very little agricultural value except as a pasture for sheep and cattle. Owing to the numerous springs it supports a good growth of pasture grass. There is a use, however, to which this type is well adapted, and that is the growth of forest trees. Wherever there is a spring on the hillside and along every ravine which carries water, there is to be found a good growth of oak, ash, elm and other hardwood trees. At Valley City this type is covered by such a growth.

The following table gives mechanical analyses of this type of soil:

MECHANICAL ANALYSES OF HOBART CLAY

No.	Locality	Description	Organic matter per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm per cent	Medium sand, 0.5 to 0.25 mm per cent	Fine sand, 0.25 to 0.1 mm per cent	Very fine sand, 0.1 to 0.05 mm per cent	Silt, 0.05 to 0.005 mm per cent	Clay, 0.005 to 0.0001 mm—per cent
9178	6½ miles S. of Valley City	Clay, 0 to 60 inches	0.42	0.00	0.08	0.08	0.40	1.08	19.28	79.10
9177	Valley City	Clay, 0 to 60 inches	.88	.42	.54	.18	.48	.81	8.02	89.52

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9177, 0.78 per cent; No. 9178, 18.40 per cent.

SIOUX FINE SANDY LOAM.

The Sioux fine sandy loam consists of from one foot to two feet of very fine sandy loam of dark-brown to grayish color, resting on a subsoil of the same texture with a depth of several feet, but changing in color at about the third foot, where, out of reach of decaying organic matter, it becomes gray. The Sioux fine sandy loam is found in the James river and Sheyenne river valleys and is of purely alluvial origin, being a wash of the finer sands of the prairie type, Marshall loam, deposited as sediment in times of high water or when these streams stood at higher levels. In the James River valley, in the vicinity of Jamestown, this type is closely associated with the type Riverwash, upon which the city itself is built. The latter type was deposited in glacial times when the James river was a torrent, while the type under discussion is a post-glacial deposit and overlies the former.

This soil, though quite limited in extent, is one of the most desirable in the area. Because of its location, it is usually well supplied with moisture, even in the driest season. This fact, together with its fine, loose, loamy texture, makes it well adapted to all farm crops of the area.

Wherever this soil is found it is under cultivation. The average yield of wheat is twenty-five bushels per acre, but forty bushels is not an uncommon yield. Flax averages twenty bushels, the average yield for barley is forty bushels, and oats sometimes yield as high as seventy bushels per acre. In the vicinity of Jamestown the soil is used extensively to supply the local demand for truck. The corn which is being acclimated to the region seems to do especially well upon this type, sometimes yielding as high as sixty bushels per acre. In the vicinity of Jamestown some alfalfa has been successfully seeded upon this soil. It is also well adapted to millet, pigeon grass and brome grass.

In a few cases this type has been irrigated and as it lies convenient to the rivers more of it will probably be brought under this form of cultivation in the future. The results from irrigated areas have so far been very satisfactory.

The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

MECHANICAL ANALYSES OF SIOUX FINE SANDY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9140	3½ miles SE. of Jamestown	Fine sandy loam, 0 to 15 inches	1.21	0.10	2.92	14.74	52.04	11.00	11.70	4.10
9142	Jamestown	Fine sandy loam, 0 to 14 inches	2.12	2.10	9.02	7.34	28.70	18.06	26.44	8.40
9141	Subsoil of 9140	Fine sandy loam, 15 to 36 inches	.87	.14	1.70	7.34	37.56	23.16	25.02	4.90
9143	Subsoil of 9142	Fine sandy loam, 14 to 30 inches	1.90	3.94	9.36	7.70	27.04	16.92	24.94	9.58

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9140, 3.99 per cent; No. 9141, 9.27 per cent.

MIAMI BLACK CLAY LOAM.

The Miami black clay loam is of a very silty or clayey texture and has an average depth of twelve inches. The color of the soil varies from dark brown to black, depending upon the amount of organic matter present and the state of its decomposition. The subsoil to a depth of three feet or more contains more clay than the soil and has less organic matter incorporated with it. Its color varies from dark brown to gray. A few concretions of iron oxides were found in the lower depths of the subsoil.

The Miami black clay loam is more or less widely distributed over the entire area and is found in depressions that were at one time ponds or small shallow lakes. There are usually little beaches of sand and gravel and some larger rocks around the outside of these depressions, showing that at some former time they were filled with water.

Since the first breaking up of the prairie some of these low wet places have been reclaimed and are now among the most productive lands of the area, and eventually all the shallow lakes of the area will give place to tracts of this soil. Probably not more than one per cent of this type is under cultivation. The type is especially adapted to the growing of hay.

Since the breaking up of the original prairie and the destruction of the prairie grass, the problem of hay production has become very serious. It would be better never to put the areas mapped as Miami

black clay loam under cultivation, but to reserve them as meadows.

The following table gives mechanical analyses of typical samples of this soil:

MECHANICAL ANALYSES OF MIAMI BLACK CLAY LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1—mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9154	1 mile NE. of Spiritwood	Black clay loam, 0 to 12 inches..................	8.74	0.32	4.74	6.80	13.90	12.04	45.30	16.58
9156	2 miles NE. of Eckelson.	Black silty loam, 0 to 24 inches..................	3.32	.28	1.22	1.72	7.02	12.32	56.48	20.96
9157	Subsoil of 9156...........	Gray silty loam, 24 to 40 inches..................	3.00	.22	.64	.88	3.70	7.84	57.26	29.38
9155	Subsoil of 9154...........	Silty loam, 12 to 40 inches	4.26	.18	.52	.90	3.58	7.28	56.16	30.98

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9154, 2.71 per cent; No. 9155, 4.78 per cent; No. 9157, 10.40 per cent.

MARSHALL LOAM.

The soil of the Marshall loam is of brown to dark brown color, has an average depth of seven inches and varies in texture from a medium fine to fine sandy loam. The first foot of the subsoil is usually of the same texture as the soil, but the material becomes somewhat heavier as the depth increases. The color of the subsoil when dry ranges from light brown in the first foot to gray in the second foot, becoming yellowish when wet. The dry subsoil heaped around the mouths of gopher and badger burrows presents an appearance not unlike that of wood ashes. Scattered upon the surface and disseminated through both soil and subsoil are fragments of rock varying from the size of a pea to large glacial bowlders.

This is the most extensive type in the area. It is typically developed east and west of Jamestown. The topography is gently undulating, marked by a succession of low hills, knolls, and shallow depressions locally known as "bog holes." In many places the latter are too wet and swampy to admit of cultivation, but since the breaking up of the prairie soil of the region many of these have become so thoroughly dried out that they are cropped with the same ease as the higher prairie soil adjoining. In several places in the area, especially in the region south of Sanborn, this type of

soil is marked by morainic hills, a few of which rise to 200 feet above the adjoining prairie.

The tops of these moraines, both on account of excessive drainage and the lighter texture of the soil, are very subject to drought and hence are of little agricultural value except for pasture. The lighter texture of the soil is due to the fact that the finer particles have been washed down to lower lying lands. This same fact accounts for the heavier phase of Marshall loam in the depressions between the morainic hills. The fact that nearly the whole area is a region of little definite drainage is very beneficial because the rain, instead of being carried off by streams and coulees, is allowed to soak into the ground. Along the James river and Ten Mile coulee, east of Jamestown, the evil effects of extreme conditions of drainage in a region of slight rainfall are plainly apparent. For a distance of from one-half mile to two miles on each side of these streams the type under discussion is so dry as to be almost worthless except as pasture, supporting only a scanty growth of wild grasses.

South and west of Jamestown only about one-half the area of this soil has ever been cultivated, while farther east it is nearly all under cultivation. The unbroken areas are covered with a dense sod of very nutritious natural prairie grass. In the depressions, where the conditions of moisture are better, this prairie grass grows very luxuriantly, and is very valuable for hay. In those parts of the area where this type is all under cultivation the need of prairie hay is sorely felt, and millet is being quite extensively grown to supply the deficiency.

Wheat, flax, oats and barley are the leading crops, and to these this soil, in a favorable season, is well adapted. In good years wheat gives an average yield of twenty bushels per acre, but under the most favorable conditions it sometimes gives as much as thirty-five bushels. The average yield of flaxseed is about fifteen bushels, but this crop has been known to yield as much as twenty-five bushels per acre. The average yield per acre of barley is about thirty bushels, and that of oats about forty-five bushels. A variety of corn is being acclimated to the type, and with a fair amount of rain and a season of ordinary length promising results are obtained.

The following table gives mechanical analyses of typical samples of fine earth of this soil:

MECHANICAL ANALYSES OF MARSHALL LOAM

No.	Locality	Description	Organic matter—per cent	Gravel, 2 to 1 mm—per cent	Coarse sand, 1 to 0.5 mm—per cent	Medium sand, 0.5 to 0.25 mm—per cent	Fine sand, 0.25 to 0.1 mm—per cent	Very fine sand, 0.1 to 0.05 mm—per cent	Silt, 0.05 to 0.005 mm—per cent	Clay, 0.005 to 0.0001 mm—per cent
9148	1 mile S. of Eckelson....	Fine sandy loam, 0 to 12 inches	3.94	0.88	2.30	2.16	6.60	10.50	62.72	14.50
9150	5 miles E. of Spiritwood..	Fine sandy loam, 0 to 14 inches	3.32	1.94	5.96	6.12	15.80	13.50	41.04	15.08
9149	Subsoil of 9148	Fine sandy loam, 12 to 40 inches	.64	6.14	9.62	7.44	18.18	12.02	29.58	16.74
9151	Subsoil of 9150	Fine sandy loam, 14 to 36 inches	1.90	2.59	6.70	5.58	12.06	12.68	39.92	19.42

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$); No. 9149, 18.60 per cent; No. 9151, 12.97 per cent.

RIVERWASH.

The riverwash consists of about twelve inches of brown or grayish-brown sandy loam underlain with coarse sand and gravel, loose shale and large shale boulders, often to a depth of fifty feet. The soil is merely a wash of fine sand from adjoining bluffs and prairies, and is a veneer over the coarse, loose, porous sand and gravel which underlies it. The subsoil consists entirely of a collection of coarse sand and gravel in the protected places along the streams when these were glacial torrents. For example, the coarse sand and gravel upon which the city of Jamestown is built was deposited on the inner bend of the river at that point. The same cause is assigned for the accumulation of the great quantities of sand and gravel in the vicinity of Valley City.

This type is also found in various parts of the area between the James and Sheyenne rivers. It is here associated with old waterways, probably unused since glacial times.

The type is locally known as "second bench land" and except for pasture is held in low esteem for agricultural purposes. In some places it is so dry that it does not furnish sufficient grass even for pasture.

MEADOW.

The areas mapped as meadow represent a condition of low, marshy depressions found in the lowest portions of the valleys outside of the James and Sheyenne valleys. The reason that no such

conditions exist along the courses of these streams is that their system of drainage is well established and there are no marshy depressions adjoining them. The type meadow is found most extensively along the "dry waterways" in the region between the James and Sheyenne rivers and represents a condition where no definite system of drainage has been established since the retreat of the ice sheet.

The meadow is closely associated with the type riverwash and Marshall stony loam, since they are all found along abandoned water courses; but it differs from the riverwash in that the latter is higher and looser in texture and, therefore, too thoroughly drained, and from the deeper phase of the Marshall stony loam in that the latter type is a little higher and adapted to the production of hay and for pasturage.

The areas mapped as meadow support only the coarsest and rankest kind of marsh grass, which has no value whatever as hay and very little as a pasture food. Under the present conditions these areas have no agricultural value except as watering places for stock, and often the water is too alkaline for that purpose. In most locations the conditions would be greatly improved by artificial drainage.

AGRICULTURAL METHODS.

The early settlers who came from the east found conditions in the northwest very different from those they left. In the area surveyed, and in the adjoining prairie region, there were no forests to be cleared and no rocks to be gathered. The pioneer had simply to build his sod house and barn, both of which were sometimes under the same roof, turn up the rich virgin soil of the prairie, and sow his seed.

The first "breaking" of the prairie sod was always shallow and with a single plow. The work of breaking began as early in the spring as possible and extended into July and August. The virgin sod is so tough that only the single plow can be used. The shallower the plowing the better, provided the grass roots are cut just below the main root. During the summer months the sod becomes thoroughly rotted and pulverizes readily when the ground is turned again in the fall. Fall plowing begins about the middle of August and continues until frost. The next spring, as soon as possible,

wheat is sown with a seeder and this is followed by a smoothing harrow. Flax is the only crop ever sown in the spring after the first plowing, because it is then too late for wheat or other small grain. Because of the fungus disease popularly known as flax wilt, flax is seldom sown upon any but new land and then only for a year or two.

After the prairie has once been broken all plowing is done in the fall. This is usually done with a gang plow, turning two furrows at a time. In order to fill the air spaces and thus prevent the furrow slices from drying out, the plow is sometimes followed by a smoothing harrow, and sometimes the plow has a harrow attachment, thus doing all the work at once. The ground is harrowed once in the spring before drilling. Wheat is sown as the first crop in the rotation. It is followed by barley and then by oats. The most successful farmers let the lands lie fallow during the fourth summer, bringing up at that plowing an inch or so of the new soil. In this way the new soil is acted upon by the weather and also by the soil bacteria during the summer and winter months. Some cultivated crop like corn is considered nearly equivalent to summer fallowing.

As yet no commercial fertilizer has ever been used in the area, and until recently many farmers have drawn their manure out in piles and burned it, believing it to be more injurious than beneficial to the soil. In the early days it had a tendency to make the growth of straw too rank, but since the productiveness of the soil has declined through constant cropping, manure has been found to have a decidedly beneficial effect. When coarse manure is turned under it has a tendency to make the soil too dry, and the manure is often drawn out in piles and allowed to rot and disintegrate before using. One popular method is to spread it upon the ground after the fall plowing and allow it to leach into the soil during the winter and spring months. Before seeding the coarse litter is sometimes raked up into piles and burned.

AGRICULTURAL CONDITIONS.

The value of the soils of the area in the production of wheat, flax and other crops is shown by the prosperity of the farming class. Until recently the thoughts of the farmers were taken up with the acquiring of land. This accomplished and a few successful crops

harvested, they have turned their attention to improving the land and beautifying the home. The sod house and barn of pioneer days have been replaced by wood and stone structures, and most of those who have been in the area for any length of time have built for themselves good, substantial houses. As yet there are only a few large barns in the area, which may be accounted for by the practice of threshing directly from the field and taking the grain at once from the machine to the elevators or cars. The necessity of large barns and sheds, however, is felt wherever stock raising is carried on as an auxiliary to grain growing. One thing which has retarded the building of large barns has been the high price of building material, nearly all of which must be brought long distances from the states of Oregon and Washington.

Ten years ago the unbroken prairie land could be purchased for $7 an acre. At that price some paid for their farms with the profits of a single crop. All those who availed themselves of the opportunity to purchase, if they have been industrious and economical, have now a good bank account and a farm clear of incumbrance, with ample stock and machinery for carrying on all farm operations.

Since then land values have been increasing, and without any additional expense on the farmer's part the value of the farm has in nearly all cases doubled and in some cases trebled. Nearly all the land in the eastern part of the area has more than doubled in value, and at present the average price is about $25 an acre. In the western part of the area, in the vicinity of Jamestown, only about one-half of the prairie has been successfully put under cultivation, and the prices range from $10 to $20 an acre, depending upon the nearness of the farms to Jamestown, or on their adaptability to the crops of the region. The days of unlimited range have ended, because the country is so thickly settled, but there are still many cattle grazing upon the prairie west of Jamestown. The land values in the western part of the area have also doubled and in some cases trebled during the past ten years, and in the future there is bound to be a continued increase in the value of agricultural lands throughout the region.

The farms of the area are nearly all operated by the owners. Those worked by tenants are rented for periods of from one to three years. It is not usual for a man of industry and economy to

work as a tenant for more than three years, because by this time he is usually able to take up a quarter section in his own name. In a locality like the morainic hills southeast of Sanborn, where the farms are rented to tenants year after year, it is usually an indication that the lands are undesirable for growing crops. In consideration for the use of his land the owner receives a share of the crop. The proportion is usually one-half of the crop where the owner furnishes half the seed and pays one-half the threshing bill. Owing to the uncertainty of the seasons, either from drought, hail or frost, it is very unusual for the tenant to pay cash rent, preferring to take the chances of getting a reasonable profit for his labor from a half crop. In prosperous times the owner usually prefers to operate his own land, because the profits are so great, and a general desire on the part of owners to rent their farms usually indicates either a series of unfavorable years or inferior land.

The size of the farms varies from 160 to about 2,000 acres, the average size being 320 acres. Smaller farms than these do not contain enough pasture for stock, and for the ordinary man a larger farm than half a section makes it necessary to hire so much help that the profits are destroyed. The prosperity of Jamestown and Valley City and the small intervening towns is in no small part due to the fact that there are no such large farms as in the Red river valley, and that the farmer, instead of bending all his energies to seeding the largest possible area, devotes more time to a better preparation of the soil. Under this system the profits in any one year may not be so large, but they are more certain.

Although the average size of the farms in the area is only 320 acres, there is a tendency toward still smaller holdings and better methods. In the western part of the area, where the rainfall is less than in the eastern part, and where, also, the soils are lighter, the most successful farmers have learned that they must combine stock raising with general farming if they are to avoid failure in unfavorable years. Where stock is kept and good use is made of the manure much better crops are produced.

The labor problem becomes a very difficult one to solve in some years, especially when the farmer owns so much land that he is obliged to hire a great deal of help to handle the crops. During ordinary seasons the demand for day laborers is met by the large force of men who come into the state from all parts of the east and es-

ecially from the nearby eastern states. But in years of exception ields the demand for men is greater than the supply and und ich circumstances the wage of labor becomes almost prohibitiv ince these men remain in the state for but a few weeks, at mo ey often take little interest in their work and their general ef ency is low. The average rate of wages paid to harvest han r the last five years is about $1.75 a day. The average for t st two years is $2.25. Occasionally $2.50 is paid, but this is n ual. The tendency is toward still higher wages, and since t ice of farm products has gone down the farmer can not afford re. This is having a salutary effect upon the prosperity of t unty. The farmer is learning that it is never profitable to ha ore land than he and his family can work, or at least no more th and one man hired by the year can work. The usual wage e year is $30 per month, with board and lodging.

Owing to the severity of climate no winter wheat is grown. Mac ni wheat has been introduced, and though it commands a pri nsiderably below that of other wheat, the fact that it yields abo third more is making it popular. Since recent experiments ha emonstrated the value of the bread made from this wheat, stron nfluence has been brought to bear upon grain dealers to recogni s value, and it bids fair soon to become an important rival of t lder varieties of wheat.

Flax has always been one of the important crops of the are standing next to wheat. As yet the farmers have not had as serio trouble with flax wilt as have the farmers in the Red River valle However, it is well recognized that flax is a crop very exhausti to the soil, and that it will not do to crop with flax continuously f more than two years in succession.

Oats and barley are among the profitable grain crops of the are As yet only a small quantity of corn is grown. The principal dif culty with this crop is that the season is not quite long enough. T variety grown is a small; inferior kind, but by careful selection seed and breeding much has been accomplished toward getting variety better in quality and better adapted to the short, cool grow ing season.

From the appearance of sugar beets seen in gardens it wou seem that this crop might be added to the products of the are but the practicability of establishing this industry on a commerci

scale should be proved by ample experiments both in growing beets and in determining their sugar content.

As yet but a few tame grasses have been grown in the area, and since so much of the prairie grass lands has been brought under cultivation the problem of hay production is becoming very serious. Brome grass has been sown by some with a fair degree of success and with utter failure by others. The experiments with it seem to show that with careful preparation of the soil it will become a valuable grass for the region. Alfalfa has been seeded on one farm in the area, but the experiment has not been under way long enough to decide definitely how profitable a crop it will prove to be. So far it would seem that it can be successfully grown. The native hay grown in the sloughs and marshes is tall and coarse, though if not allowed to become too ripe is very nutrious and makes excellent feed for both cattle and horses. That produced upon the higher and drier soil is fine and short and is considered somewhat poorer in quality than the product of the lowlands. The average price for unbaled hay is about $5 a ton. Millet is grown quite extensively for hay. The quality is good, but it is almost entirely for cattle, not being considered a desirable feed for horses. Potatoes are grown for local consumption. In quality and size they are scarcely excelled by those grown anywhere. The average yield is about 150 bushels per acre. No potatoes are shipped out of the area because of the great distance to markets.

Owing to the constant demand for grain, the farmers of this section are always sure of a ready market for their crop. Two grist mills, one at Valley City and the other at Jamestown, together consume more wheat than is grown within the area surveyed. Yet not all of the wheat is sold to these mills. The numerous elevators along the railroads, by their active competition with the mills, cause large quantities of wheat to find a market at the mills at Minneapolis, St. Paul, Duluth or Superior. Later in the season it becomes necessary to ship in wheat to keep the home mills running. During the season of 1903 the Valley City mill alone was compelled to import 110,000 bushels. A conservative estimate of the amount of wheat that will be ground by the two mills during the season of 1903 is 1,000,000 bushels. About one-half of the flour is sold within the borders of the state, one-third of the remainder in the western states, and the remaining amount is shipped largely to

Boston, whence much of it is exported to the British markets. A great deal of the barley is used for malting purposes and is disposed of chiefly in the nearby eastern cities. The flax is sold in Russia, and the oats, of which large quantities are grown, are nearly all consumed on the farms where they are produced, or within the towns in the area.

Situated along the main line of the Northern Pacific railroad, the area is in direct communication with both the eastern and western markets. From the east this road brings in immense quantities of farm machinery, while from the state of Washington it serves as a direct route for the importation of the building material so necessary to the development of this treeless region. The Minneapolis, St. Paul & Sault Ste. Marie railroad, passing through Valley City, forms a second direct line to Minneapolis and St. Paul and joins the area with the grain belt of the great northwest. These two lines, by their close competition, give the region excellent transportation facilities in both their freight and passenger departments. From Sanborn a branch of the Northern Pacific railroad extends through a fertile region to McHenry, about fifty miles to the north. Another branch of more importance crosses the main line of the Northern Pacific railroad at Jamestown, connecting on the north with the Minneapolis, St. Paul & Sault Ste. Marie line and the Great Northern railroad, and on the south with branches of these same roads.

Along each of these lines are frequent grain stations, with elevators, which give the farmers excellent storage facilities with a minimum amount of handling. Besides the advantage accruing from good storage facilities at these elevators, the farmer has the satisfaction of seeing his grain graded before it leaves his own hands. From Eldridge to Valley City, a distance of forty-two miles, there are nine of these stations where elevators are located. A few of the farmers load their grain directly into the cars on their own responsibility, and while the practice saves the expense of storage it has the disadvantage of delaying the grading until after shipment and of placing all risk of loss by leakage on the shipper.

SUMMARY OF THE REPORT ON THE CANDO AREA.

By E. O. Fippin.

During the summer of 1904 a soil survey was made covering 288 square miles in the southern part of Towner county. (See progress map, figure 1.) The state through its Agricultural and Geological Surveys, cooperated with the bureau of soils of the United States Department of Agriculture, furnishing two men who assisted the bureau's men (for about forty days) in the prosecution of the field work.

This survey included the preparation, on a scale of one inch to the mile, of a soil map showing the area and distribution of the different kinds of soil, and a report describing these soils in their relation to the crops now grown and the agricultural methods in use, together with a discussion of the improvement of agricultural conditions and the development of crops especially suited to the climate and the soils. The map and report will be published and distributed in the usual way by the Department of Agriculture. We are enabled, through the courtesy of the bureau of soils, to give here a brief summary of this report.

The area surveyed includes the southern eight townships of Towner county, and occupies an undulating, treeless prairie, eminently adapted to agriculture, as evidenced by the good average yields of all the crops grown. The general elevation of the surface ranges from 1,475 to nearly 1,600 feet above sea level. The two largest towns are Cando and Maza, on the St. John's branch of the Great Northern railroad.

The drainage system consists of several large, shallow and sluggish streams called coulees. Big Coulee is the main stream, and most of the others empty into it, the water finding its way finally into Devils lake. There are also numerous other small, shallow depressions found on the rolling upland and between the elevations, where water accumulates to form swamps.

The superficial material of the region, in some places reaching to a depth of more than 100 feet, has been deposited through the agency of glacial ice. The original glacial till has subsequently been considerably modified by the floods that attended the retreat of the ice margin. It was this large volume of water passing

through the area that formed the coulees and left the large deposits of fine material which enters into several of the local types of soil.

Five types of soil, differentiated by an examination of the surface material to a depth of three feet, have been recognized. Each is characterized by peculiarities of texture and drainage, and has a distinct crop producing power. Their common characteristic is that they contain a relatively high percentage of organic material, and are consequently dark in color.

Areas of a gravelly soil occupy knolls and ridges slightly elevated above the surrounding country, and because of its porous texture and consequent perfect drainage, it produces light crop yields.

Limited areas of fine, sandy loam were found, generally occupying slightly elevated positions. The soil is of a rather fine sandy or silty texture, and because of its slightly elevated position and good drainage it is an early soil, better fitted to the production of corn and vegetables than to the cereal grains.

Most widely distributed of the types recognized is a loam. The soil consists of about twelve inches of heavy, black, sandy loam or loam, under which are mingled clay and gravel of the glacial till, rich in calcareous material. It is naturally productive soil, but the yields are considerably influenced by the seasons.

Next in extent to the loam is a silt loam, which is found chiefly in the eastern half of the area. It is of a friable texture, easy to cultivate, and withstanding unfavorable climatic influences better than most of the soils. It is best adapted to grain, and on the whole is considered the most productive soil of the area.

Scattered in small patches throughout the area are found the clay soils. These always occupy low, undrained swales, and unless thoroughly drained are unfit for any agricultural purpose other than grazing and hay production.

GENERAL CONDITIONS.

There is a comparatively small amount of alkali in the soils, which is found in the poorly drained positions where the texture is finest. Small spots in the grain fields are occasionally injured. More complete drainage and thorough, careful cultivation will do much to correct this evil. Thorough removal of the drainage water, which holds the salts in solution, will in the course of time

remove much of the excess of salts, and cultivation will tend to prevent its accumulation at the surface by preventing evaporation.

The chief factor that controls the crop yields in the area is the moisture supply, and this fluctuates from year to year with the variation in the amount of rainfall. Those methods which aim at storing in the soil the largest amount of water, and holding it until such time as it can be made to assist plant growth, give the best yields of crops. Deep plowing and the maintaining on all plowed surfaces of a mulch of two or three inches of loose soil will do much to attain this result.

SOIL SURVEY OF THE MINOT AREA.

By Rex. E. Willard.

Location of the Area. — The area included in this survey is located in Ward county, in the region known as the Mouse River valley. The middle point of the southern boundary of the area is four miles north of the city of Minot. The area surveyed embraces a tract six miles north and south by twelve miles east and west, and contains therefore seventy-two square miles, or 16,080 acres. It comprises two congressional townships, which for convenience will in this paper be described by their congressional designations, viz. township 156 north, range 82 west, and township 156 north, range 83 west. They will be referred to as 156-82 and 156-83 respectively.

The soil types and the general characteristics of the area here described are thought to be fairly representative of a vast area in Ward, Bottineau and McHenry counties. This portion of the state was once the scene of a vast lake covering within the present state of North Dakota an area of 6,250 square miles, besides an approximately equal area in Canada. The area chosen for this investigation and described in this paper is so situated that the soils formed (a) by the deposit of sediment on the old lake bottom; (b) those modified by the action of waves and currents along shore, and (c) those of the higher land beyond the limits of the area covered by the lake, are represented.

History of Settlement. — North Dakota is one of the younger in the sisterhood of states, and this portion of the state has been set-

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y of Settlement.—North Dakota is one of the younger in rhood of states, and this portion of the state has been set-

tled only a very few years. Five years ago there was scarcely a shack outside of the city of Minot, and no roads were to be seen except those old Indian trails leading from far away towns to some trading station.

When the people of the United States and of other countries began to learn of the opportunities of the poor man in this region there was a grand rush to secure desirable farms. Many settlers had little idea of the labor and hardship that must be exercised if they desired to be successful.

The homesteader builded his 6x10 "shack" and began his existence on the prairie. According to law the homesteader must make a certain amount of improvement upon the land or he would be liable to have his claim contested.

Generally a few acres of sod were broken and a little flax seed sown. As all implements and horses were expensive, the first year's work was frequently not well done, most desiring to fulfill the law as easily as possible. As a rule the "breaking" was not more than two inches deep where it should have been at least five inches. As the country was subject to drouth, these methods were not successful.

Farm machinery has always been expensive and the poor settler must get along with as little as possible. For these reasons the land was not well worked and the drouth had a much more serious effect than it otherwise would.

By these methods the moisture, which was scarcely ever plentiful, was quickly evaporated. The crops then suffered.

Flax was usually the first crop to be sowed, as it brought the largest financial returns for the least amount of work. Of all crops flax injures the land most, and when sowed successively for several years the land is materially impaired.

By these methods and the fact that the soil is somewhat sandy, people were led to believe that agricultural pursuits could not be successfully carried on, as year after year the crops were injured by drouth.

As more settlers came and learned by experience, methods were improved. It was found that by breaking and plowing to greater depths there would be less danger of crop failure. Gradually, as the settlers became more well-to-do, they were able to have a better class of machinery and spent more time working the land before

crops were sown. However, even at present, many do not see the value of a thorough cultivation of the soil.

As the land is worked more thoroughly and more is broken up there is much less fear of drouth, although the annual precipitation is practically the same.

Agricultural development has been very rapid, and land that was formerly considered worthless now produces good crops. This is due to a large extent to the improved methods of farming.

Climate. — The growing season in North Dakota is short. The ground is generally frozen until some time in April. Frequently it is considerably later before seeding can be done. The crops ripen in August generally. Frosts may be looked for in September. The ground freezes so that fall plowing ceases usually early in November. Severe storms have been known to occur in September, though not commonly. The winters are cold, but usually the weather is steady and not subject to extreme fluctuations, so that the atmosphere is healthful and invigorating. Winter usually sets in in November, and the ground often remains frozen until April.

When a heavy snowfall occurs in the early winter the farms are not materially injured by the cold. The snow is very dry, and as it is usually accompanied with wind it is packed into drifts hard enough to bear the weight of a horse. On the general level of the prairie there is not usually a heavy body of snow, but houses have been nearly covered by the piling drifts. The temperature frequently stands from —20 degrees to —30 degrees F., and —40 degrees has been known, though such extreme cold is not common.

Physiography. — The surface features of North Dakota, except that portion west of the Missouri river, have been derived from glacial activities. The Mouse river winds its course through the northern part of the state. It enters the state at about 102 degrees west longitude, and forms an ox-bow which encloses about 6,250 square miles of area. This flat or basin was once covered by an immense body of water known as Glacial Lake Souris.

The area surveyed and described in this paper is located in part on the old lake bottom and in part outside the territory covered by the lake. Townships 156-82 and 156-83 were mapped with regard to the general character of the land, its agricultural value and types of soil as determined by examination of texture and fertility.

The Mouse river cuts across the southwestern corner of 156-83, but the river bed is not included in the area surveyed. Egg coulee, one of the largest channels in the region, extends through the northeast corner of 156-82. The area is cut by many coulees and glacial channels. Morainic hills and "pots and kettles" and fairly level prairie are also found in the area.

The altitude of the area is from 1,600 to 1,700 feet above sea level. In the eastern part of the area is a broad expanse of level or slightly undulating prairie which was formerly a portion of the bed of Lake Souris. The shore-line through the area extends from the southwest corner of 156-82 in a direction somewhat west of north through 156-83.

West of the shore-line the surface is more hilly, being morainic in origin and character. The hills are rough and stones occur in large numbers upon the crests of the hills. Between the hills are many "pots and kettles" or depressions which have such a heavy subsoil that water is held in some of them continuously.

East of the shore-line of the old lake the surface is more level, and is therefore better farming land. In the northeastern portion of 156-82 the surface is broken by many small hills. Between these are many small and shallow depressions. These hills were originally morainic hills, but owing to the action of the lake water they have been worn down and appear smaller and more regular than those in the western part of the area.

Many channels or coulees occur zigzagging across the area in various directions. These are generally deep and narrow. About the heads of these coulees is often a flat fan-shaped area. A low area may have a general slope from all sides toward one place which appears to be the head of the coulee. The channel immediately becomes deep and the banks serrated by many cuts and irregularities.

The coulees in the western portion drain into the Mouse river, but those of the east and south discharge into the locality of 156-80 and seem to disappear. These latter have a more abrupt beginning than those of the west. Without any warning a channel is observed to have a zigzag course across the country. These channels were probably made by glacial waters. They have contained much more water in ages past than at present. Only in the spring is there water at all, and then no perceptible erosion occurs on their bot-

toms. Many beds of gravel and sand are found along these channels. These were undoubtedly deposited by swiftly flowing water. A large portion of the bottom of Egg coulee in the northeast portion of 156-82 is heavy gravel.

Terraces or "benches" are of frequent occurrence on the banks of the larger coulees. These are generally of the sandy or gravelly character.

The hills in the southwestern portion of 156-83 are a part of a terminal moraine. The large stones and the general character of the hills indicate glacial origin.

Ward Silt Loam. — The soil type that covers the largest portion of the area will be termed, for convenience, Ward silt loam. The soil is from ten to twelve inches in depth. It is of reddish-brown or brown color and is a fine, sandy loam. It sometimes contains a very small amount of gravel, generally of limestone. The subsoil is usually of two or three strata. A stratum of sandy loam will be encountered and a stratum of silty material which contains scarcely any grit. It is probably derived from a limestone formation. Below there is a stratum of heavy, tenacious loam. This is variable in color. Frequently there are mottled streaks of red and gray in a brown loam. Sometimes large amounts of gypsum are encountered. This loam continues to a considerable depth.

The type covers the central and western portions of 156-82 and the northern half of 156-83. Much the same material is found in the soil of another type, that of the low hills. The Ward silt loam covers an area of gently rolling country, which contains many "pans," or shallow depressions of a few square rods in area. These "pans" are not generally cultivated, as water sometimes stands in them years at a time. Luxuriant grasses, which grow in these, make excellent stock food.

Although coulees in the form of deep channels occur upon the type, it is not drained to more than a slight extent. Frequently there are sloughs and "pans" which contain water all summer. The coulees do not drain the land for more than a few rods from their channels.

This type was formed by the waters of Lake Souris. Originally this was all morainic or hilly country. The action of the water has leveled the surface and left this soil.

A large variety of crops may be grown on this type. Wheat and flax are grown most extensively. Barley, oats and spelt are raised to considerable extent for stock fodder. Flax is usually sown upon fresh "breaking." This crop many times realizes a larger profit for less work than wheat, but has been found to be much more exhausting to the land.

This type is well adapted to raising truck products. Whenever truck products are planted, the improvement in the small grains in the following years is very noticeable. Trucking is a sure method of killing weeds. By trucking the land every few years the weeds are kept down, the land is benefitted and a fair profit is realized at the same time.

The yield of wheat is generally from fifteen to twenty-five bushels per acre, of flax from ten to fifteen bushels, of oats from twenty-five to forty bushels. On exceptionally good seasons forty to fifty bushels of wheat are raised and twenty to twenty-five bushels of flax. From sixty to seventy bushels of oats have been raised on a wet season.

Ward Sandy Loam.—In the southern part of 156-82 is a type of soil which will be called Ward sandy loam. This type covers only a few square miles, being found in the southern tier of sections of this township. The soil is about twelve inches deep. It is reddish-brown sandy loam and is usually very fine. There are frequently a few small pebbles. The subsoil contains less sand than the soil, and is tenacious and heavy. It is of brown color, containing mottled streaks of red (Fe) and gray (Ca Co 3). Quite large amounts of gypsum are also in evidence. The surface of this type is slightly undulating. There are few stones or bowlders.

There is very little drainage. The surface slopes towards the coulees for only a few rods from their banks.

This type is only a variation of the last discussed and might be classed with it. It was formed by the deposits of Lake Souris at the same time that the before mentioned hills were worn down.

The crops on this type are much the same as those upon the one last considered. The subsoil is somewhat heavier than that of the previous type and will, therefore, hold more water. This makes the crops show up somewhat better upon this type than upon the others. There is seldom too much rain during the growing season and so the land that will hold moisture is in greater demand. The

price of this land is appreciably higher than the most of that included under the last preceding type.

Morainic Sandy Loam.—The type which may conveniently be called morainic sandy loam is located in the northeastern half of 156-82. This portion of the area embraces the remains of a moraine that has been leveled to its present form by the action of the waters of Lake Souris. The morainic hills have not been worn to a level prairie but have been left in the form of small hills or knolls with depressions between them.

The type might be mapped as two separate types; one embracing the small hills and the other the depressions. The soil and subsoil of the hills differ from those of the depressions. However, it would be a difficult matter to illustrate the types, as the separate hills and depressions are of such small area. Each hill contains scarcely eight acres and the most of the depressions are even smaller.

Upon the high land the soil is from four to eight inches in depth. It is brownish sandy or gravelly loam. The subsoil is sandy, gravelly or stony loam.

In the low land between the hills the soil is from eight to ten inches in depth. It is of a heavy character, being sticky when wet, and is quite tenacious. The subsoil is still heavier, being silt loam, and is also very tenacious. It is of a brownish color. It contains some streaks of mottled red and gray.

The surface of this type is very different from that of any other. Small hills and knobs are alternated with low, hard "pans" and even "pots and kettles." There are no large areas of either low land or high land.

The type as a whole has no drainage except Egg coulee, which drains only a few rods from its channel. The water as it falls upon the higher lands immediately gathers in the clay bottomed "kettles" between the hills and here remains until it is removed by evaporation.

About one-fifth of the land of this area has been broken up and is at present under cultivation. The crops are principally flax and wheat. Unless there is an abundance of rain the crops are likely to be light. The uplands are too dry and gravelly to be advantageously cultivated and the low lands are too wet and heavy. Only a small portion is left for cultivation and only in limited areas. Wild grass grows luxuriantly in the low, wet depressions. If these bot-

toms dry out sufficiently the grass is cut for winter fodder. This type is not well adapted to farming. Grazing is best adapted to this area.

Morainic Loam. — The morainic hills in the southwestern portion of 156-83 constitute a type of soil very different from any previous type. This area is entirely out of the lake bottom. The hills stand up rough and rugged as left by the ice. The type consists of soils of different characters; the soils on the hills differ widely from those of the depressions. This type might be divided into two types. It would be difficult to map the hills as a separate type from the depressions as each occurs only in small areas. The character of the soil on the hills and in the depressions is so different that each would form a type of itself if correctly mapped.

The soil on the upland is only from two to four inches in depth. It is gravelly or stony loam. The subsoil is gravelly or sandy. In some places the hill tops are so stony and gravelly that little vegetation can sustain itself.

The sides of the hills vary; in some cases the soil and subsoil are heavier and considerable vegetation appears, while in other places the land is almost barren. The soil on these hillsides varies from coarse to fine sandy loam.

In the hollows or "pots and kettles" the soil is 14 to 18 inches in depth. It is generally heavy loam containing large amounts of decayed vegetable matter. It is usually of black or dark brown color. The subsoil is of much the same texture, though often somewhat more sandy. The soil is always wet and sticky and the subsoil is very tenacious.

This type is typical of a morainic country. The hills are from 30 to 60 feet above the bottoms. On some of the hills the bowlders are so numerous that one may walk across without touching the ground.

There is no drainage except as the water runs from the hills to the bottoms between. There are many swamps and even small lakes which have no outlets.

This moraine is only one of many in North Dakota. Its course may be traced from the vicinity of Minot into Canada, and far southward across the state.

Only a very small portion of this land is being farmed. This is due to the roughness of the surface and the non-fertility of the

soil. The best occupation to be carried on is grazing. There are some very successful ranches at the present time. Buffalo grass grows to some extent upon the hills and grasses of many varieties grow in the sloughs.

Ward Gravelly Loam. — Along the coulees and channels is found a considerable amount of gravel which for convenience will be called Ward gravelly loam.

The soil of this type is from 4 to 6 inches in depth. It is of brownish color and owing to its looseness of texture is not very fertile. Generally sand and gravel are apparent. The subsoil is somewhat heavier but still contains considerable gravel. In some localities almost pure gravel is found to a considerable depth. The gravel found in the channel of Egg coulee differs somewhat from the others. The gravel stones are larger and are more numerous. Some are as large as the fist.

These gravels are deposits from glacial streams. Terraces occur along most of the large channels. In every case the gravel has been deposited by the waters of ancient glacial streams. The waters that flow in the channels at present scarcely leave a trace of erosion from year to year. Small areas of gravel are found along the coulees which are too small to be shown on the map.

This type occurs in the southwestern part of 156-82 and also in the channel of Egg coulee in the northeastern part of 156-82. The whole area of Ward gravelly loam does not cover more than a few sections.

The vegetation on this type is not heavy. Where crops have been seeded they are not usually successful unless there is plenty of rainfall. The grass is small and wiry and weeds are plentiful.

As yet no crop seems to have been applied that was well adapted to the type. Grazing is the most profitable use to which the land has thus far been put.

Ward Clay Loam.—The low, heavy land of this area has a type of soil somewhat different from any other land in the district. There are two kinds of low land which may be taken up separately. There are broad channels which extend entirely across the area. There are also many small areas of low land which have much the same type of soil.

The broad flats are old glacial channels. One of these contains a part of sections 2, 3, 10, 11, 12, 13, 14, 15, 22, 23, 24, 25 and

26 of township 156, range 83. This divides, and one branch joins another flat or channel in township 156, range 82. This one is smaller, partially containing sections 4, 5, 8, 17, 18, 19, 20, 29, 30, 31 and 32. These channels, in such cases, have high bluffs bordering, while in some places there is no definite division between the channel and the level prairie.

The small areas, referred to, are dried up sloughs or lakes. These usually contain only a few acres of land. They are found in sections 3, 9, and 22-23, of township 156, range 82. In township 156, range 83, they are found in sections 29 and 28-27-34. One of the channels has its beginning in township 157, range 83. The head is much the shape of a fan. It spreads out over five or six square miles. In this particular channel there is a coulee, but the coulee is not of the same formation as the larger channel. There is some water in the lowest part, but is entirely stagnant.

The soil in these channels and flats is from 10 to 18 inches in depth. It is of a black or dark brown çolor. It contains large amounts of decayed vegetable matter which makes the soil very fertile. The soil is heavy and tenacious and usually contains considerable moisture.

The subsoil is a large, heavy loam of very fine sandy loam. It is of grayish-brown color and sometimes contains small amounts of mottled red. In the channels the subsoil seems to be in strata, while in the open flats the subsoil is usually uniform. Small elevations of gravel occur in the channels, formed by ancient glacial waters. These have been discussed under Ward gravelly loam. In a few cases there are large morainic deposits in the channels forming quite large hills. (See sections 10-15, township 156, range 83.) These are gravelly or stony on the surface.

The low-land flats, i. e., the dried up sloughs or small lake bottoms, are not generally good farming land. The soil in these is from 14 to 18 inches in depth. It is heavy, black loam containing much decayed vegetable matter. The soil is fertile but is generally covered with water until too late in the season or is baked too hard to be tillable. The sod when turned appears hard and tough. The subsoil is heavier than the soil. It is usually grayish-brown with some streaks of red and white.

These pans have a waterproof bottom. Water once in them can only get out by evaporation. These low tracts are of small

area containing only a few square rods. Some, however, are several acres in extent. They appear most frequently among the hills but are not infrequently found on the prairie.

Only in the spring of the year, when the snows are being melted, is there any flowing water in the coulees. The water seeks the low beds of the channel and forms "pot-holes" which frequently hold water the year around. These sloughs afford excellent hay in large quantities but cannot always be harvested on account of the standing water.

These channels were all made at the time of the ancient glacier. Some large bowlders in these bottoms show deep striations caused by the action of the ice.

All the small grains may be raised on the type called Ward clay loam. However a very small acreage of this type has been plowed. The general surface is not well adapted to farming on account of excess of water during the seeding season. When the season is dry the top soil bakes into a very hard crust. On some of the best of this type very good crops have been raised and will perhaps average up with the surrounding prairie.

In all probability these soils were formed by the waters of some time long past. The waters carried the finer material and deposited it in the depressions. In many of these the clay underneath is many feet deep. Very infrequently sand is found to some extent but clay is invariably found at a greater depth.

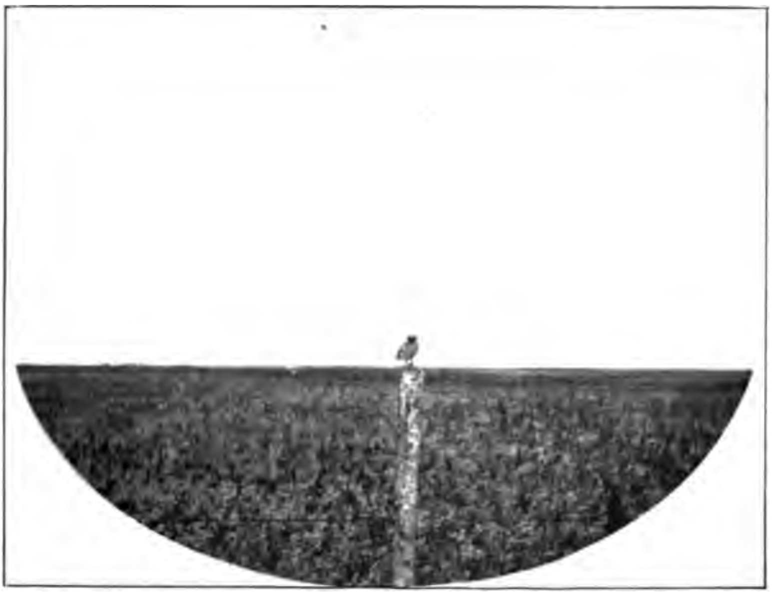
Water.—The many sloughs and small lakes which occur in this district have been referred to in connection with other types. Some of these bodies of water, which are large one year, may be perfectly dry the following year according to the amount of rainfall.

The soil and subsoil under the water of these sloughs is very similar to that of the heaviest of Ward clay loam. If these could be drained very fertile land would be obtained.

This surface water contains no alkali. In none of the low, wet lands was alkali observed. Crops were injured to a slight extent by what appeared to be an excess of lime. This only occurred in one locality to any extent and here only in small area. This occurred in section 14, township 156, range 82.

Water Supply.—The water supply of this region is abundant, but the quality of the water is not always good. Every farmer has a well of water and not infrequently two. One of these is usually for the purpose of watering stock and the other for domestic purposes.

Morainic Lake Filling with Vegetable Matter. (Muskrat house in center.)



One of the First Occupants of the Soil.

The wells range from only a few feet to 150 feet in depth. They average about fifty feet in depth. The deeper wells usually furnish an abundant supply of water, but it is frequently more or less alkaline. Some are so salty that they are bitter and very sickening to the taste. Others are almost pure.

The shallower wells are usually near the house. The water from these is used for household purposes. These are seldom alkaline and are fairly pure unless surface water seeps through into the wells. The water from the shallow wells is not generally very hard.

It frequently occurs that the water from the deeper wells is not alkaline when first used. In some cases it has been a year before any bitterness was detected. If the water is used continuously and in large quantities the alkaline feature is not observed for a considerable time. If not much water is used and the well stands idle a good deal of the time it has in some cases become so alkaline that stock would not drink it when at first the water had little if any bitterness.

Alkali.—The soils of this area are very free from alkali. On the level prairie there is not enough alkali to injure the crops any whatever. In some places there are indications of an excess of lime which is particularly injurious to flax. In some of the low lands there are slight traces of alkali. This small amount is only the accumulation of that which was formerly on the higher elevations. The water washed it in, and there evaporation left it.

Some of these flats have been drained. Considerable trace of alkali was seen. In wet seasons the alkali would have no effect upon the soil, but in dry seasons the effect would be more noticeable.

Methods of Agriculture.—A steady improvement may be seen from year to year in the agricultural methods in use by the farmers. At present the greater number have had some experience and understand that the land must be well tilled in order to have good results.

A large amount of plowing is done in the fall. Many times a farmer does not seed all his farm. He summer fallows or plows directly after the crop is taken off in the summer. Many do not harrow the summer fallowed land until just before seeding, but experience has shown that the land will hold much more moisture if thoroughly harrowed.

Deep plowing is everywhere better than shallow, but not all have yet learned that the best results are obtained in this way.

As soon as the summer crop is off the land and the rush of threshing is over, the fall plowing begins. This is continued until the ground freezes. In the spring plowing is taken up where left off in the fall.

The soil is, as a rule, fairly well harrowed. Disc and shoe drills are used altogether for seeding.

The harvest is carried on by means of large binders and headers. The most of the grain is threshed in the field where cut. Very little is stacked or housed before the arrival of threshers.

Threshing is carried on on a large scale. Immense traction engines are used in place of horse power. These are set in order with separator in the middle of a field of shocks. The grain is hauled to the machine from the shocks and hauled away in large grain tanks. The grain is either stored in granaries or hauled directly to the elevator on the railroad. A well-equipped threshing crew will generally thresh 3,000 bushels of grain in a day; 5,200 bushels are reported to have been threshed by a single machine.

This rapid threshing is not usually as well done. Much grain is carried through the machine and left in the straw pile.

A large variety of grains may be raised in this region. Wheat, flax, barley and oats are the chief grains. Millet and spelt are also raised to some extent.

The best rotation of crops has been found to be as follows: Wheat, barley, oats, flax. If truck products can be raised in place of oats or barley the land will be noticeably improved, as shown by the crops that follow.

General Conditions.—The farmers at the present time are fairly well-to-do. None are very poor, though few are forehanded. Some have borrowed money to prove up their claims. Usually a high interest must be paid upon this money, which makes it still more difficult for the farmer to get started. One good crop, however, will place nearly every one now incumbered in a position to fight all future contingencies. The farmers thus far have become more and more prosperous from year to year. As fast as the new and improved methods of farming are introduced, just so fast the farmer finds himself in a better condition.

A very small portion of the land is held by speculators. This is either rented or lies idle. Very few farms are rented, and where so they are generally poorly farmed. Any good, progressive farmer will not rent but will own a farm of his own.

The problem of hired labor is one of the most important. Men come into the state for the summer's work and then out again. Their only desire is to make as much money as possible with little work. Frequently these men are poor farmers and are therefore poor laborers.

Wages are high compared with that of the class of laborers and work of other states. A monthly wage of $30 is usually paid for five or seven months, beginning with April. Day laborers in harvest time receive from $2 to $3 per day. The laboring class is small in numbers and it is frequently a very difficult matter to obtain sufficient laborers to carry on the harvest.

The Great Northern railroad and the M., St. P. & S. S. M. railroad pass through the city of Minot. Each furnishes fair freight service. Large elevators are located on each railroad and grain is hauled to them in large quantities. As nearly as may be estimated the average price of hauling grain on the public roads is ½ cent per bushel per mile.

The roads are usually prairie trails, and are only graded where the worst sloughs are encountered. On account of the sandy texture of the soil these roads are seldom muddy except in the low lands.

The grain markets are generally good. Wheat and flax are sold at a fair discount from prices in St. Paul and Minneapolis. Only a small portion of the grain is shipped by the farmers, but is sent through the elevator companies.

THE SURFACE FORMATIONS OF SOUTHEASTERN NORTH DAKOTA.

By Daniel E. Willard.

In common with most of the northern states, nearly all of North Dakota and Minnesota is covered with a mantle of drift due to the presence of the great ice sheet. Eastern North Dakota was affected directly by the ice in a manner much like that of other parts of North America over which the ice passed. The area is deeply mantled with drift or till. In addition to this a belt including approximately the eastern tier of counties of the state is covered with a deposit arising from the melting of the great ice sheet known as lacustrine silt. Streams upon the adjacent land surfaces were kept at flood by the waters from the melting ice, and large volumes of sediments were swept into and down these streams. Sandy beaches, washed by the waves, became the assorting grounds of the coarser sediments conveyed into the lake waters, and off-shore currents became the builders of sand bars. The finest rock flour or silt was that which came to rest in the still waters of the lake far from shore. The Sheyenne delta, a vast mass of sand, gravel and shale transported from the margin of the melting ice sheet or eroded from the plain over which the waters flowed, is an illustration of the great work done by the flood waters from the melting ice. The large amount of shale in the delta deposits and the depth to which the ancient glacial river eroded its bed below the drift mantle into the underlying shales outside the Red River valley indicate the vast work of erosion and transportation accomplished by the waters of the melting ice sheet.

The region immediately west of the Red River valley was not covered by the waters of Lake Agassiz. This is a region of till or bowlder clay of the same character as that lying beneath the stratified lacustrine sediments of the Red River valley. The bowlder clay is composed in part of materials transported for greater or less distances by the ice, but is mainly the pulverized materials plowed up along the course of the moving ice, as is shown by the similarity of the drift clay to the stratified clay-shale below revealed in the records of well borings.

The surface deposits of southeastern North Dakota are drift materials, those in the Red River valley being modified by the action of

New Era Road, Near Fowler Farm, Cass County.

Lone Poplar Trees on Sandy Beach of Lake Agassiz.

the waters of Lake Agassiz. Below the modified lake deposits is the till, similar in character to that of the rolling prairie beyond the area covered by the lake. The total depth of the drift, as determined from well borings and from the deep valley of the Sheyenne, is from forty to sixty feet upon the rolling prairie in the western portion of the area now considered to 200 to 250 feet in the axial portion of the Red River valley. The depth of the drift varies considerably owing to the uneven surface of the preglacial landscape. Four types of drift deposits occur in this portion of North Dakota. These are (a) the fine sediments deposited in the deep waters of the lake and known as lacustrine silt; (b) the reworked drift represented in the beach ridges and other shore deposits; (c) the delta deposit made by the Sheyenne river; and (d) the rolling prairie with low morainic hills.

Lacustrine Silt.—The lacustrine silt deposits overlying the till extend westward of Casselton and embrace the region southward beyond Wahpeton and northward beyond Grand Forks. Its greatest thickness is as much as sixty feet and it is commonly as much as thirty to fifty feet. This deposit consists of the finest particles of rock brought into the lake by streams or washed from the wall of ice which formed the northern shore of the lake. This finest rock flour from the great continental ice mill was laid down in perfectly stratified layers in the quiet waters of the lake, the upper layers being blackened and enriched by accumulations of carbonaceous matter from the decomposition of plants and animals which found a habitat in its cold waters and in the shallow marshes which succeeded the disappearance of the lake. These blackened marshes in turn became the dry meadows of prehistoric days.

The Sheyenne Delta.—The great delta plain of the glacial Sheyenne river covered the southern one-third of the Casselton quadrangle and the southwestern corner of the Fargo quadrangle. This is a sandy plain representing the coarser sedimentary deposits of this once great river. The total area of the delta is placed by Upham at 800 square miles, and is estimated by him to have an average depth of forty feet. The northern and eastern front of the delta in Cass and Richland counties rises quite abruptly sixty to seventy feet from the almost perfectly level surface of the lacustrine sediments of the old lake bottom beyond the limits of the delta. The deposit is one of fine sand and fragments of shale with a scant admixture of clay, so that the texture is in general quite loose. The surface of the plain

is gently undulating, at times approaching a rolling topography. Dunes of wind-blown sand are conspicuous landscape features over portions of the delta. The plain is intersected by the valleys of the Sheyenne river, by which the delta was formed, and by the lesser Maple river. Both these streams have eroded deep gorges in the delta deposit. The valley of the Sheyenne is nearly as deep as the total thickness of the delta itself, though no points where the underlying till has been cut into have been observed.

The steep front of the delta on its northeast side near the village of Leonard is marked by benches or terraces formed by the action of the waves after the waters of the lake had fallen below the higher plain of the delta. The most conspicuous of these is the Campbell beach, which also marks the most prominent "bench" forming the line of demarcation between the black lacustrine sediments and the reworked drift of the beach deposits in the region to the north of the delta. The existence of this beach along the front of the delta and below its highest level, and the occurrence of the highest or Herman beach along the western or shore side of the delta plain, show that the time of formation of the delta by the glacial Sheyenne river was during the highest stages of Lake Agassiz, or between the Herman and the Campbell stages of the lake. The present deep valley of the Sheyenne river was therefore excavated in its own delta during the higher stages of the lake while the waters of the lake were being drained southward by the river Warren.

Sand Dunes.—The most marked region of dunes on the portion of the delta included within the area under consideration is a tract from three to ten miles in width along either side of the Sheyenne river. Where the river crosses its own delta it has eroded a channel from sixty to eighty feet deep, its banks steep, with short, deep and steep-sided coulees. The occurrence of dunes is on the grandest scale in the neighborhood of the larger lateral coulees. Wherever the turf becomes broken by erosion so as to expose the sands, or where the covering of grass is thin, the lightness of the soil permits the scooping out of hollows and piling of sand into hills.

Springs of the Delta.—The loose texture of the delta allows the ready percolation of the waters of rainfall and melting snows. There is little erosion of the plateau of the delta because the surface waters are so readily taken up by the soil. The waters percolate downward until they are checked by restraining strata of materials of a

Wind Blown Sand Encroaching Upon the Valley North of Walcott.

Old Baldy, a Large Sand Dune, Richland County.

more clayey character in the delta itself, or by the hard, impervious till which forms the floor beneath the delta deposits. The ready percolation of the waters and the impervious beds of clay make the occurrence of springs common along the delta front and in the deep channels of the rivers. On the lower plain of the lake bottom beyond the delta the hydrostatic pressure of the surface waters penetrating the ground upon the higher land of the delta causes the water table to rise to the surface of the ground, and considerable areas are rendered quaking, boggy marshes.

The northeast front of the delta, about midway between the Sheyenne and Maple rivers, near the village of Leonard, is intersected by several deep coulees which have been formed by the action of springs bursting out from the delta. These may fittingly be called "traveling springs," since they travel backward into the plateau as a result of the action of their own waters in removing the erodable materials out of which they emerge. The same mode of "traveling" is observed in the springs which head the coulees along the valleys of the Sheyenne and Maple rivers. The spring half a mile west of Leonard village has eroded a gorge two miles in length with a maximum depth of seventy feet. Other coulees in the vicinity are half a mile to nearly two miles in length, formed in the same manner. Such springs occur in the banks of the Sheyenne river along its course outside the Red River valley for 150 miles in Ransom, Barnes, Griggs, Nelson and Eddy counties, where the valley of the river is cut deeply into the soft cretaceous shales which underlie the drift.

Beaches of Lake Agassiz.----West of Casselton is a belt about six miles in width extending from the northern edge of the Sheyenne delta northward with varying width beyond the limits of the state. This is a tract having the characteristic topography of a wave-washed shore of a receding sea. The western side of this region marks the highest point reached by the waters of Lake Agassiz.

On this tract the 1,100-foot and 1,000-foot contours are separated by intervals of only about three miles, whereas the 900-foot contour is about forty miles to the eastward of the 1,000-foot contour near the Red River of the North.

The slope between the higher contours represents the eastern face of the Manitoba escarpment. The region was covered by the waters

of Lake Agassiz during its highest stages, and was relieved of the covering of water as the lake receded. Well marked gravelly and sandy ridges traverse the area in a generally north-south direction. These are the beach ridges formed by the action of the waves and currents of the lake upon the shore. The ridges are composed of whitish sand with a little clay, and gravelly places are frequent. Sand for building purposes and gravel for road construction are obtained from pits. The eastern slope, or front, of the beaches is usually more steep and higher than the western, or back, side, and a marshy tract often lies back of a ridge, drainage to the lower levels to the east being prevented by the ridges which act as barriers. The area is one of reworked drift and lacustrine deposits, some places where the configuration of the shore was not such as to cause breakers to accumulate sand and gravel in ridges being covered with true lacustrine deposits.

The highest wave-marked ridge is known as the Herman beach, and this represents the height of the water at the time of its greatest extent. The recession of the lake was not gradual, but was by stages of intermittent recession and pause. The next lower stage than the Herman was the Norcross, represented on this area by a ridge about four miles in extent lying along the boundary line of Eldred and Walburg townships, and another fragment about two miles in length in Wheatland township. Fragments of beach ridges representing the upper and lower Tintah stages of the lake occur along generally parallel lines at intervals. North of Leonard village the Tintah shore is marked by an escarpment eroded by the waves in the front of the delta. That the Tintah beaches represent two stages or levels of the lake is shown by the fact that the two nearly parallel lines connecting fragments of well defined ridges are separated by a vertical interval of about twenty feet.

The most conspicuous beach on this area, unless it be the Herman, which is conspicuous because it delimits the lake area from the rolling drift topography to the westward, is the Campbell, which extends from the point where the Maple valley debouches upon the level plain of the lacustrine sediments in a generally northward direction. Frequent gravel- and sand-pits occur along the course of this beach. It is in part a well defined ridge, rising with a sharp slope on the east or lakeward side, and falling a less amount on the west or landward side, and in part an eroded cliff or escarpment

The Herman Beach, Near Absaraka.

Geological Excursion of a Class from Agricultural College to Herman Beach.

The Campbell Beach at Wheatland.

Banks of Sheyenne River West of Fargo.

formed in the drift clay or till by the cutting action of the waves of the lake. This beach is a conspicuous landscape feature and marks the principal boundary between the level area of the lacustrine sediments and the reworked drift which forms the "bench" land bordering the old lake bottom.

The McCauleyville beach, which marks the lowest stage of the lake while its waters were drained southward by the river Warren is very feebly developed in this locality. It is represented by two fragments not exceeding a mile each in length in Walburg and Gill townships respectively. This beach is elsewhere a conspicuously developed ridge bearing sand and gravel and traceable continuously for many miles.

The beaches just described as occurring on the western side of the lake, also occur on the east side of the valley, the several beaches representing the higher stages of the lake occurring on a gentle slope facing westward between Hawley and Glyndon, Minnesota. Bowlders occur in great abundance on this slope. Some of these bowlders are of immense size, and their distribution along the higher shore lines of the lake suggests that they may have been carried by floating blocks of ice and stranded upon the sand bars off shore.

The Unmodified Drift.—West of Magnolia station and Sheldon the land was not covered by the waters of Lake Agassiz, and the region is therefore beyond the limits of what is known as the Red River valley. This is an area of rolling and undulating drift, the topography being that of the type which characterizes much of the eastern half of the state of North Dakota west of the area of the ancient lake bottom. The 1,100-foot contour coincides in a general way with the highest line marked by the action of the waves of the lake. Succeeding contour lines marking twenty feet of vertical distance follow rapidly toward the west, two contour lines crossing many of the sections, these lines running nearly parallel with each other and with the Herman shore line. As has been before noted, there is a fall of only 100 feet in about forty miles from the Campbell shore line eastward to the Red River of the North.

Morainic Islands and Beaches.—An embayment of the ancient Lake Agassiz existed in the southwestern part of what is now Cass county, nearly midway between Magnolia and Sheldon. North of this embayment is a hill about two miles in length and averaging about one-third of a mile in width, which was an island in Lake

Agassiz during a short time at its highest stage. Southward from this island a similar hill having a width from north to south of two miles projected as a promontory or headland into the ancient lake; a neck of land about a mile in width connected this promontory with the general highland a mile west. These hills are typical morainic hills, being composed of hard bowlder clay with occasional sandy or gravelly layers, and bowlders of granite, quartzite and limestone.

Extending for a distance of three miles in a north and south direction between the eastern extremities of these highlands is a conspicuous gravelly beach-ridge. This ridge marks the line of the "breakers" between these two highlands at the time of the second Herman stage of the lake. Another segment of the second Herman beach about two and one-half miles in length lies two miles north of the northern extremity of the island just described, and half a mile east and twenty feet lower than the highest Herman shore. Five miles further north a feebly developed shore line representing the second Herman stage lies at about the same distance east of the upper beach and separated by about the same vertical interval..

Lagoons Back of the Beaches.—Thus the island referred to was an island only for a short time, viz., the period, whatever its absolute length, during which the lake stood at the level of the upper Herman beach. During the second or lower Herman stage of the lake the region embraced in the embayment lying west of the island was an overwash slough or, lagoon, the waters which were driven by the winds across the "breaker" line forming a broad pond or shallow lake back of the beach ridge.

In a similar manner lagoons or sloughs were formed back of the high ridges formed at different stages of the lake. It is thus that sandy marshes, which occur frequently back of the sandy or gravelly beaches, are explained. The breaking of the waves where the lower part of the rolling mass of water was retarded by the friction of the bottom caused the coarser gravel and sand to be thrown down in more or less uniform layers, forming the beach ridges which have been described, the finer sand and silt being carried over the crest of the bar, where these settled in the still water of the lagoon. The soil of these lagoon tracts is thus frequently not only composed largely of fine sand and silt, but the soil is often impregnated with alkali derived from the continued evaporation of the lake water during the existence of the lake, and from the accumulation from evaporation since the disappearance of the lake.

THE GEOLOGY OF THE SOILS OF SOUTHEASTERN NORTH DAKOTA.

By Daniel E. Willard.

Lacustrine Silt.—Probably there are few regions in the world which exceed in fertility of the soil that of the Red River valley. The soil consists of the finest of rock flour ground and pulverized by the great ice sheet and borne into Lake Agassiz by the inflowing streams. Only the very finest of the assorted sediments thus distributed by the waves and currents of the lake were deposited in the deeper portions of the lake, as the coarser materials were thrown down when the inflowing streams were slackened by the still water. Only the finest could remain in suspension in the water till they came to rest in the deep water of the central lake. This finest powder of rock is known as lacustrine silt, and when wet and compacted together has much the character of clay, differing from clay in that it contains fine sand, fine powder of limestone, and carbonaceous matter, and does not have the coherent properties of clay.

"Gumbo" Areas.—Areas varying in extent from a few square yards to a few square miles of very compact and heavy soil occur upon these level bottoms through which water percolates very slowly, and when dried by the intense heat of summer forms hard blocks, the surface cracking into characteristic geometrically formed prisms. These are known as "gumbo spots." This soil is very sticky when wet and hence not readily worked in farming pursuits. Owing to its tendency to bake into hard blocks and its impermeability to water, which renders drainage difficult and frequently causes accumulation of alkaline salts, the gumbo areas are not as desirable lands for farming purposes.

River Alluvium.—Bordering the rivers upon the plain of the Red River valley, river alluvium forms a mantle which overlies the original fine lake sediments, thinning from a thickness of several feet at the river banks to an attenuated sheet at some distance from the stream channels. This material is the fine overflow deposit from the rivers and is slightly more coarse in texture than the lacustrine sedimentary deposits. These deposits are coarser nearer the river banks because the heavier particles are the first to be deposited. A cross section of the alluvial banks, therefore, would show a wedge

of coarser materials graduating in fineness into the lacustrine silts farther away from the river. Thus the land slopes away from the rivers, and is not infrequently too low and wet for advantageous farming at a little distance from the river while dry and suitable for farming near the river.

These alluvial soils are among the most productive of the region. Their looseness of texture renders them capable of more easily taking up the moisture of the summer rains, and also of drainage from the excessive moisture of melting snows and spring rains. The looseness of texture also permits greater freedom of natural underdrainage so that the soil is less impregnated with alkaline salts than are the lacustrine sediments generally.

Subsoils.—The subsoils have the same general character as the soils proper, the former being the original from which the latter, by the transforming processes of atmospheric agencies and the addition of organic matter, have been formed. The subsoils, however, show distinctively the mode of their deposition from water, being in definite strata or layers. Many of these layers are of a fine grained clay-loam character bordering on clay, but are not so heavy but that they are penetrated by water. They are generally sufficiently porous to permit of a slow percolation of surface water to lower depths and of capillary rising of water toward the surface, this condition being favored by the atmospheric and organic agencies which produce soil. This quality is of great importance in determining the value of the lands for agricultural purposes, as it renders natural underdrainage possible and permits the slow rising of the waters during dry seasons from the permanent water table below. These stratified subsoils differ in structure from the unstratified till in the regions beyond the limits of the lake bottom and also from the till which underlies the stratified deposits chiefly in the assorted and stratified character of the materials.

The deeper till is the preglacial soil and the broken and pulverized rock shoved along the bottom and carried in the ice of the moving glacier. The till consists of clay, bowlders, gravel and sand, gravel and sand often occurring in locally stratified layers or beds. The clay, in its deeper portions, is a dark blue, becoming brown nearer the surface where acted upon by the atmosphere. Below where it is penetrated by vegetable roots and burrowing animals, and beyond the active changes of heat and frost, this bowlder clay is a firm and

Ash Trees, Five Years Old from Seed, Agricultural College Farm.

Three-year-old Apple Tree, Agricultural College Farm.

Flowing Well and Milk House, North of Woods.

Group of Cattle Grazing on Ranch near Sheldon in Cass County.

Old Farm Machinery Buried by Sand Thrown Out of Budke Artesian Well, South of Wheatland.

compact substance offering a high resistance to the percolation of waters. So-called surface wells are often not surface wells at all, when by surface wells is meant such as derive their water supply from percolation or seepage from the soil in the immediate vicinity of the well, but are obtained by penetrating a layer of nearly impervious clay below which a water-bearing vein of gravel or sand is struck, the clay acting as a restraining wall to hold the water.

The Water Table.—The permanent water table is high in this region, due principally to two causes. These are that the deeper subsoil or till is nearly impervious to water, thus preventing underdrainage, and the level character of the land by reason of which a very slow progress of the soil water toward the streams results. The soil and subsoil are sufficiently porous to allow a very slow percolation of the water, and the deeper clay acts as a vast dish holding the water.

Alkali in the Soil.—The question of alkali in the soil is one of great importance. In some localities the alkaline salts in the soil become a hindrance to agriculture. The percentage of salts in the soil is found by analysis to increase with the depth. Not infrequently shallow surface wells furnish abundant supplies of water. This is sometimes of excellent quality, but sometimes it is so highly impregnated with salts as to render the water unfit for drinking or even for the use of stock or for steam boilers. The use of water therefore from surface wells is not general.

As the surface waters evaporate and deeper soil waters rise by capillarity, alkaline salts are brought to the surface and there, by rinsing from melting snow and spring rains these are removed to the streams wherever there is surface drainage. Lower places toward which surface drainage tends and from which there is no escape for the waters, become in time by the concentration from continued evaporation what are known as "alkali spots." "Gumbo spots" are often of this character, the subsoil being so compact that underdrainage is reduced to practically nil. The alkali becomes gradually more in amount, and these places become unproductive as a result.

Because of the removal of the soil alkalies and other salts by the surface waters the waters of all the streams contain some amount of alkaline and other salts, and because there is alkali in all the soils and subsoils and also in the deeper till, all the well waters contain some greater or less amount of mineral impurities. The waters may

be soft and suitable for washing purposes and for drinking, still there are no pure waters. For the most part the amount of alkaline and other salts in the deeper wells is not so great as to seriously interfere with the obtaining of supplies of reasonably pure and suitable water for domestic and general agricultural purposes.

As all the soils and subsoils are of drift origin, it follows that the ultimate origin of the alkaline and other mineral substances was in the stratified rocks of the preglacial land surface. The salts are therefore those that were carried in the waters of the ancient Cretaceous seas, on the bottom of which these rocks were originally deposited as sediments.

While the alkalies in the soils are sometimes a detriment in the unwholesome effects upon the character of the waters for domestic uses, and sometimes also are present in so great a quantity as to render small areas of land unproductive, yet on the whole the alkaline and other mineral salts in the soil of this area add greatly to its productiveness as when present in not too great quantity they furnish necessary plant food, and add greatly to the fertility of the soil.

GEOLOGIC HISTORY OF EASTERN NORTH DAKOTA.

By Daniel E. Willard.

In but very few places in the eastern portion of North Dakota is there an exposure of the underlying stratified rocks. Our knowledge of the rock formations which form the floor underlying the drift, those rocks which were the surface formations before the invasion of the great ice sheet, is therefore derived largely from artificial borings. Deep wells have penetrated the hard granite on the Fargo quadrangle at 252, 255, 256, 266, 286, 295, 298 and 475 feet; and upon the Casselton quadrangle at 411, 450, 470 and 490 feet. The only formation of the sedimentary series which is passed through in these wells is a shale formation containing layers of sand, Cretaceous age. Thus there is no record preserved in the rocks of this area of the time represented by the Cambrian, Lower Siberian, Upper Silurian, Devonian, Carboniferous, Triassic and Jurassic eras.

The Cretaceous shales and sandstones rest unconformably upon the granite complex. The upper portion of the Cretaceous strata

"Pictured Rock," Fort Ransom. After the Rocks Came Man. (The surface of the boulder was polished by glacial action. The marks are Indian hieroglyphics.)

The Last Standing Vestige of Old Fort Abercrombie.

g Well and Stock Barn, Red River Valley. (This is what man builds on North Dakot soil after the days of pioneering have passed.)

After the Aborigines Came the Pioneers. (Sod House Southeast of Lisbon.)

shown in the structure section was the surface of the land over which the ice of the great ice sheet passed, and the till overlying this was deposited from the melting ice. The upper stratified layers shown in the section must not be confused with the stratified layers of the Cretaceous formation. These are of much later time, and are the sediments deposited upon the bottom of glacial Lake Agassiz at the time of the melting away of the ice of the great ice sheet, and known as the lacustrine deposits or lake sediments.

The Older Sedimentary Rocks of the Red River Valley.—No Palaeozoic strata have been encountered in borings upon the upper portion of the Red River valley, but older formations have been observed in deep borings down the valley toward the north. At Grafton, 100 miles north of Fargo, an artesian well penetrated 317 feet of limestone belonging to the Ordovician, and 288 feet of Cambrian shales and clays. (Upham.) How far these strata extend southward in the Red River valley has not been determined. Several artesian wells obtaining their water supply from the Dakota sandstone occur in the region lying between Grafton and the present area, but none which penetrate deeper.

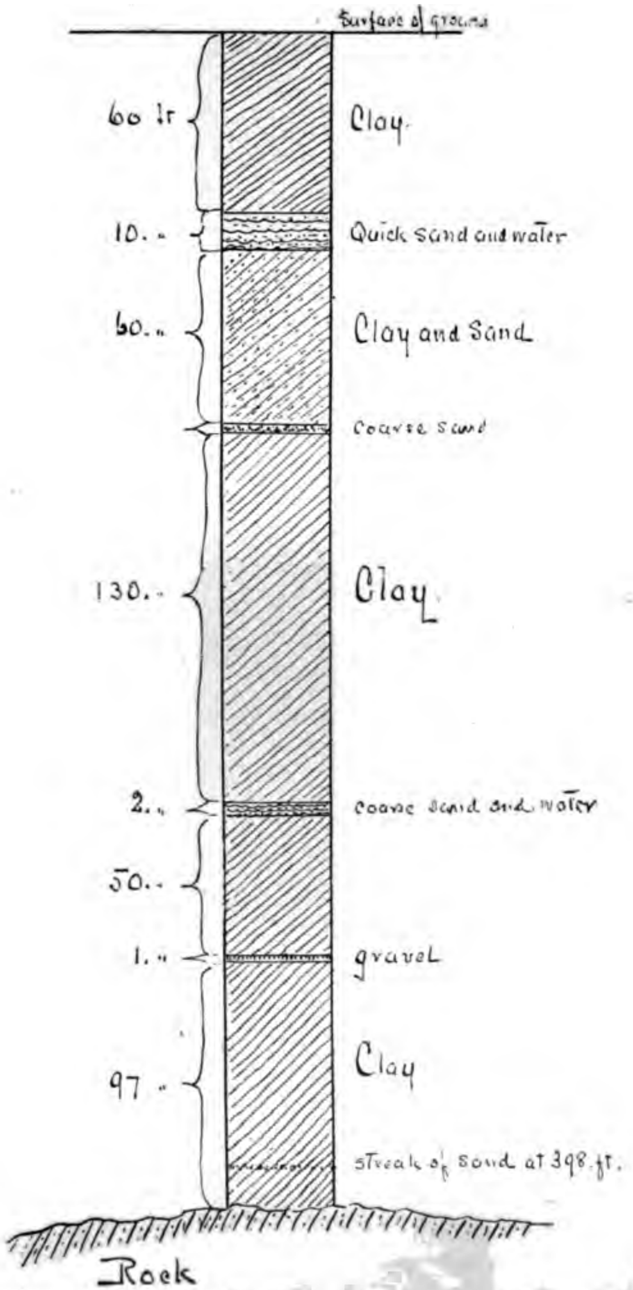
The sedimentary rocks of the eastern portion of North Dakota were deposited in a great inland sea which, during Cretaceous time, occupied a large area in the interior of the continent. All the strata encountered in borings in this portion of the state, except the granite bed rock, are shales and sandstone deposited as sediments in this great sea. The depth at which these strata are encountered to the westward in artesian wells shows a dip westward toward a syncline which has its western limits on the flanks of the Rocky Mountains and southward in the Black Hills.

Post-Cretaceous Erosion.—The present Red River of the North occupies nearly the position of a large northward flowing stream by which was formed the great depression now occupied by the level plain of the bottom of glacial Lake Agassiz. The excavation of this great valley occurred after the deposition of the Cretaceous sediments, probably when the great post-Mesozoic uplift of the western part of the continent rendered the former sea bottom dry land. The preglacial Red River valley therefore probably represents a period of erosion continuing from the close of the Cretaceous period and Mesozoic era through the later uplift of the Tertiary. The present Red River of the North flows at a height of many feet above that

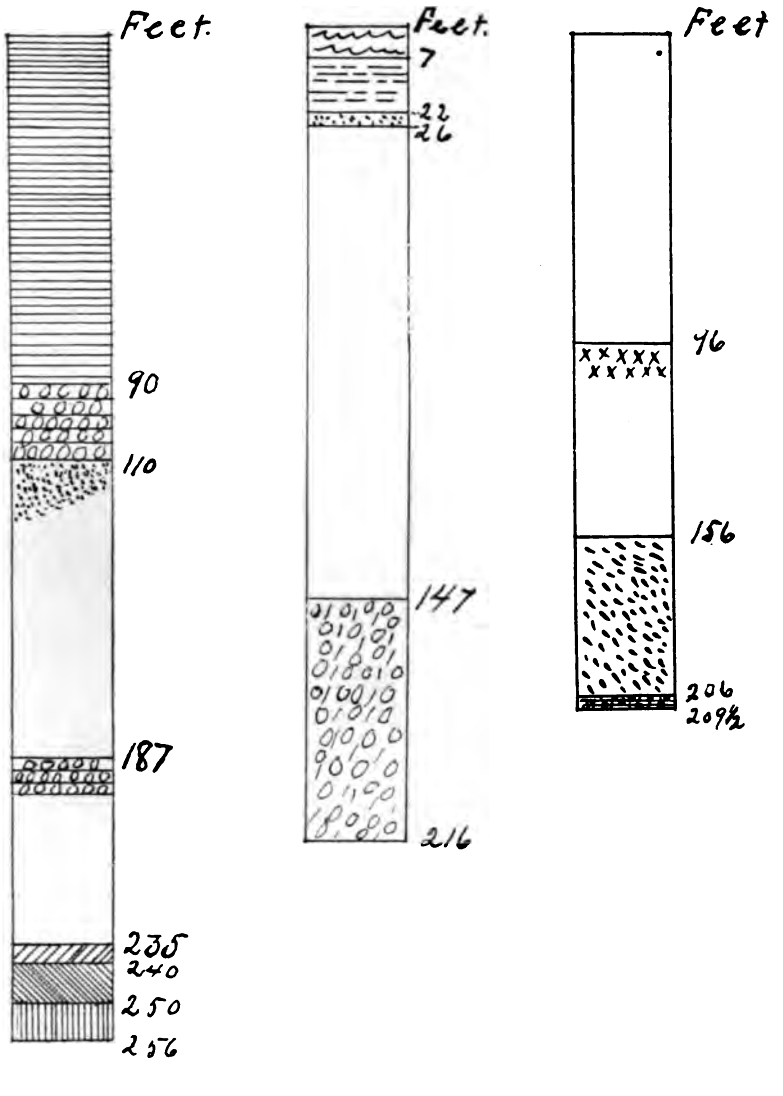
of the older river which occupied the same great valley and drained the basin now occupied by the level plain of the bottom of Lake Agassiz. This old valley was deeply mantled with drift, borne southward by the moving mass of ice, and the present river flows on the top of this.

The Manitoba escarpment, an outcropping of the Cretaceous shales which forms the highland limiting the Red River valley on the west, was thus formed by the erosion of the valley to the east, the cut-off edges of the Cretaceous sediments constituting the escarpment. If these strata once continued over the whole southern portion of the Red River valley in North Dakota and Minnesota, as seems most probable, they have been largely removed by erosion. The total thickness of the shales and sandstones in the axial portion of the Red River valley on the latitude of Fargo does not generally much exceed 150 feet, as determined by borings. However on the western border of the Red River valley their depth is unknown, as no borings have penetrated to the granite. The deepest borings, none of which in the Red River valley exceed 600 feet in depth and those of the adjoining territory to the west not exceeding 800 feet, reveal successive layers of shale and sand.

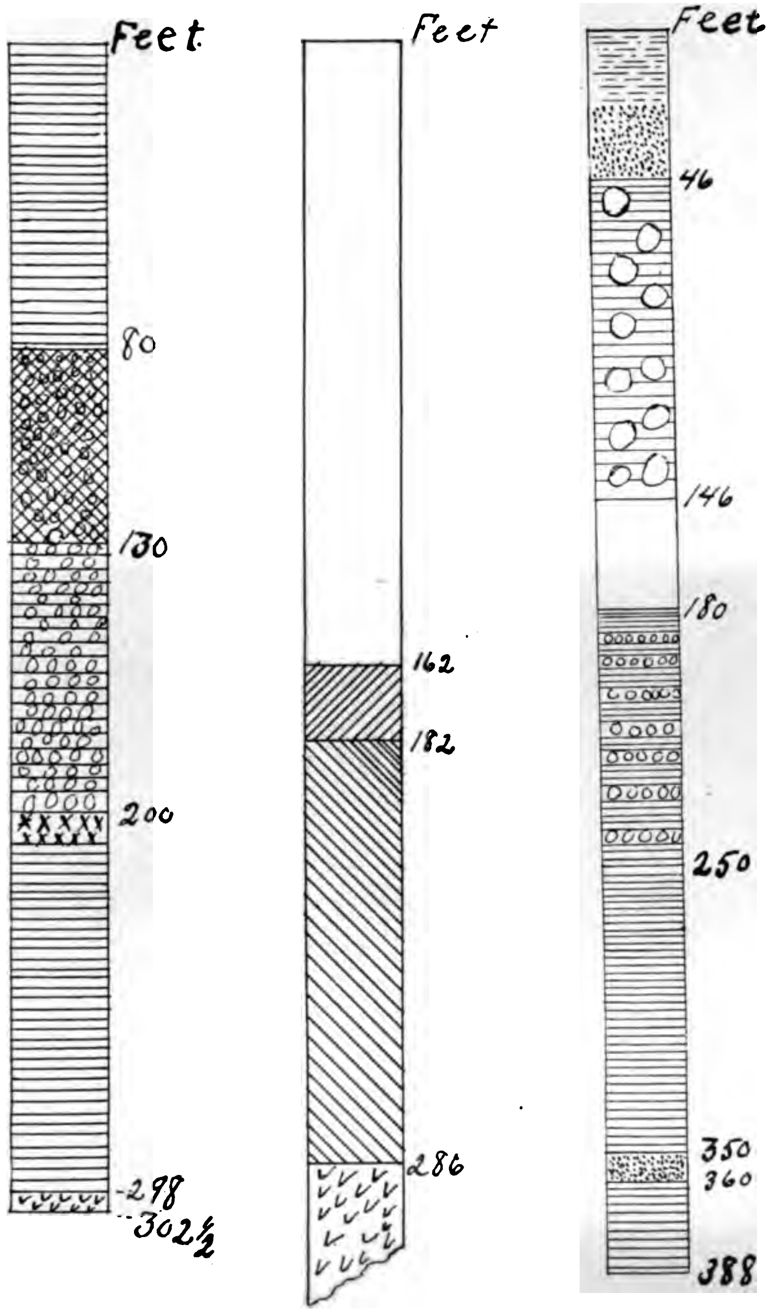
The Cretaceous Formations.—Water bearing sands are encountered at different depths throughout the southeastern portion of the state. The deeper sands have been generally referred to the Dakota formation. It is somewhat problematical whether or not the Benton formation underlies the drift in this portion of the Red River valley. Fossils are not often obtained from borings and few outcroppings of the stratified series occur. The exact age of the strata which form the floor beneath the drift can therefore be only provisionally stated. Excellent exposures of the Pierre shale occur in the Manitoba escarpment seventy to 100 miles north of the latitude of Fargo, where numerous small streams descend to the plain of the Red River valley from the higher lands to the westward, and have eroded deep canyons into the soft shale. This escarpment rises more than 100 feet above the level plain of the ancient lake bottom a few miles south of the international boundary and 100 miles north of the latitude of Fargo and Casselton, having an elevation above sea level of 1,500 feet. (Upham.) This highland descends gradually southward to approximately 1,200 feet above sea level where it crosses the western portion of the present area.



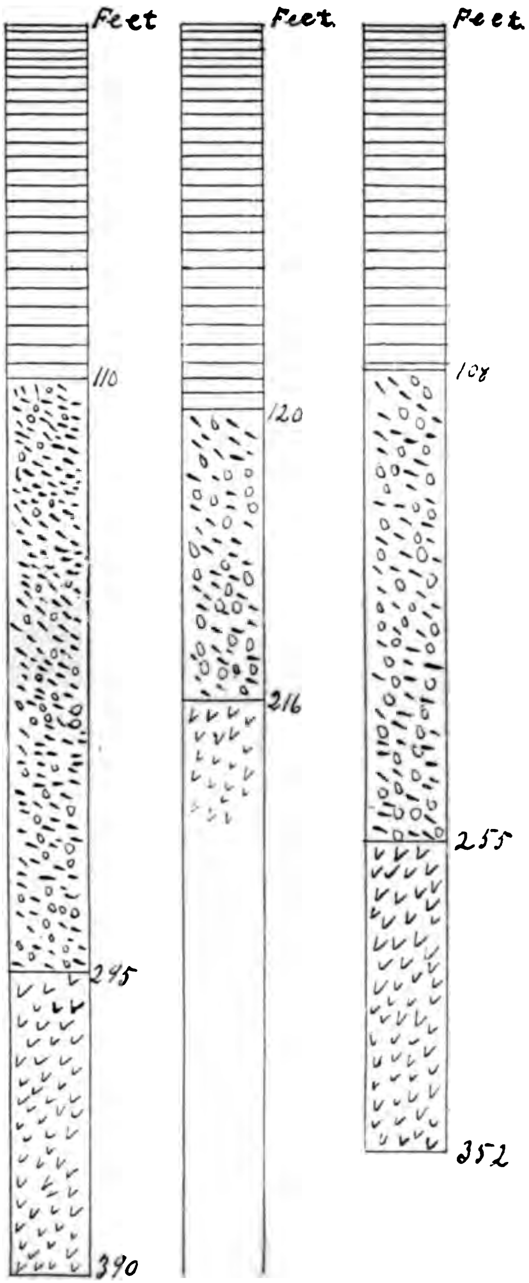
Well on Douglas Farm, Cass County.



Well Sections, Fargo Quadrangle.



Well Sections, Fargo Quadrangle.



Well Sections, Sec. 36, Tp. 141, R. 48.

Near the point of debouchure of the Sheyenne valley into the Red River valley, about ten miles southeast of Lisbon, outcroppings of shale occur in the sides of the glacial Sheyenne valley which have been by Upham provisionally referred to the Benton. Also shale penetrated in deep borings at several points in the upper Red River valley have been provisionally referred to the Benton by the same authority. (U. S. G. S. Monograph XXV, p. 92, also chapter x.)

The "second clay" of drillers is encountered in the vicinity of Fargo at depths of less than 200 feet to 300 feet. Clays described by drillers as "light green," "decided green," and "white and chalky," and "putty-like" are reported at depths of 208 feet to 250 feet, and in the deep well at Moorhead at 370 feet. These clays in every case extend down to hard granite at 252 feet to 298 feet, and in the Moorhead deep well to 475 feet. In the last named granite was penetrated all the way to 1,901 feet.

In the vicinity of Casselton the "second clay" is struck at 200 feet to 300 feet, and deeper clays or "third clay," with layers of hard pan and gravel at 300 feet to 520 feet. White clay is reported from wells in the vicinity of Casselton at 292, 300 and 420 feet respectively, with hard granite below, and hard granite at 411, 450, 470 and 490 feet respectively. Flowing wells are not obtained in the vicinity of Fargo, the line of the eastern limit of the Dakota artesian basin being a few miles east of Casselton. However, deep wells yielding water from a fine white sand rock are common about Fargo, in which the water rises nearly to the surface of the ground. If these sands are provisionally assumed to be Dakota in age, and hence regarded as the eastern continuation of the Dakota artesian water bearing sands farther west, here immediately overlying the granite, it would then be natural to correlate the "second clay" of the Fargo and Casselton areas with the Benton shales farther west. Until fuller field records have been obtained upon the territory to the south and west, it seems of doubtful utility to attempt to definitely assert the age of the clay and sands underlying the drift and covering the granite bed rock of the upper portion of the Red River valley.

The Structure Section.—A structure section from western Minnesota across the Red River valley on the latitude of Fargo shows the granite bed rock immediately underlying the Cretaceous shales and sands, the former passing beneath the latter toward the west. The Cretaceous formations have a westward dip toward the great

synclinal basin in which the latest formations within the state of North Dakota were deposited as sediments in the great inland sea. The outcropping edges of the Cretaceous strata in the Manitoba escarpment represent post-Cretaceous erosion, by which the great preglacial Red River valley was formed as a trough across the eastern edge of the great syncline. The glacial deposits, till and lacustrine sediments, represent the later work of the glacial period, and the somewhat broken line marking the upper limit of the section represents the present land surface.

Over all the region included in this paper borings penetrate below the drift into Cretaceous shales and sands, and upon all except the western one-third of the area below these into hard granite. The lowest of these Cretaceous strata, and upon the eastern portion of the area, it may be the only one, is the Dakota formation. Farther west and beyond the Manitoba escarpment the Benton, Niobrara and Pierre shales are encountered in ascending order.

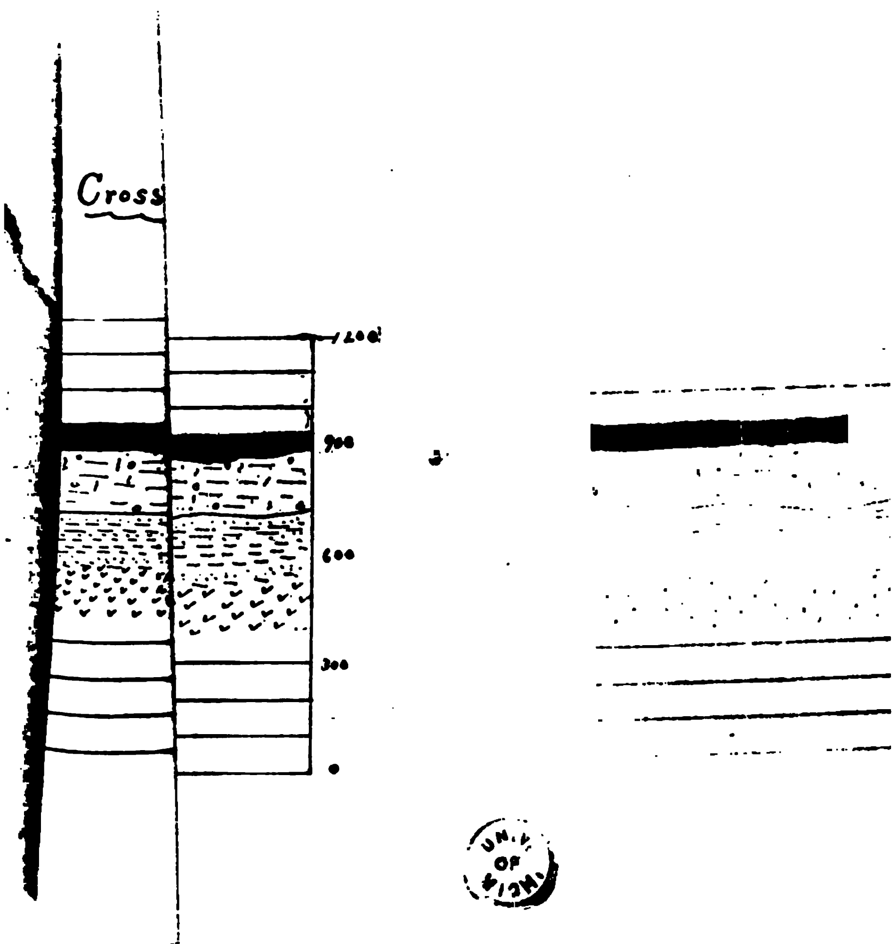
The occurrence of the Benton upon the floor of the Red River valley has been discussed elsewhere in this paper.

The deepest borings in the territory immediately west of the Red River valley do not penetrate below the Dakota sandstone, but it may be supposed that at some distance west successively older formations would be encountered at still greater depths, and finally the granite bed rock at the bottom and below all.

The occurrence of artesian wells which derive their water from a sandstone formation, over much of eastern North Dakota, is explained by the structure of the synclinal basin which extends westward from the region of the Red River of the North to the Rocky Mountains, and southward to the Black Hills. Flowing wells from the Dakota sandstone horizon are obtained at depths of 200 feet near the eastern limits of the artesian basin, at 400 to 500 feet upon the western portion of the Red River valley, at depths ranging from 650 feet to 800 feet twenty to thirty miles west of the Red River valley, and still farther west in the valley of the James river at 825 to 1,500 feet.

The western outcropping edges of the Dakota formation flank the eastern highlands of the Rocky Mountains, and the Black Hills, and it is from these regions that the water is supposed to be derived. Here the rains penetrate the porous sandy formation lying at the surface at altitudes from 4,000 to 6,000 feet above sea level, and trav-

erse the sandstone layers to the eastern portion of the syncline. At Jamestown and Devils Lake the water bearing formation is encountered at about sea level. The artesian water bearing horizon of the Dakota formation rises to about 700 feet above sea level upon the



and the much later shale can be at present given, was very great.

The occurrence of white and green varicolored clay, from five to fifty feet in depth, and in the deep well at Moorhead 105 feet, overlying the hard granite, indicating a decomposed and much changed condition of the granite, shows that the granite was long exposed to

the action of atmospheric agencies before the surmergence of the old land surface and the deposition of the Cretaceous sediments.

That the Cretaceous sediments overlying the granite were also laid down in a shallow sea is shown by thin beds of coal encountered in the sandstone formation which overlies the granite, and which has been referred to the Dakota.

THE WATER SUPPLY.

By Daniel E. Willard.

Dependence Upon Wells.—The southeastern portion of North Dakota is intersected by the Red River of the North and several tributaries, each entrenched in a well defined channel. The larger of these streams are never dry, and the smaller only during very dry seasons, but owing to the generally level topography of the region their currents become very sluggish during the summer, and the water, which receives organic matter from the banks along their courses, is therefore not suitable for household purposes without filtering and boiling. It is, however, used for stock by those farmers whose buildings are situated near the banks of the streams. The Red River of the North is the source of the general supply for the cities of Fargo and Moorhead for street sprinkling, lawns, fire protection and laundry purposes, not however for culinary or general domestic purposes. The supply from streams which is within practicable reach of the inhabitants of this portion of the state for any purpose is limited to the comparatively few who live near the banks of the larger streams. By far the greater number of the inhabitants are so situated that a water supply from any stream is impracticable, and the dependence is upon wells. The Red River of the North, with its principal tributaries, the Sheyenne, the Wild Rice and the Maple, are the only perennial streams, and but few coulees intersect the intervening lands. Outside the cities of Fargo and Moorhead probably fully nine-tenths of the population is dependent upon wells for a water supply for all purposes, while not more than one-tenth could without great labor and inconvenience obtain their farm water supply from streams.

Springs.—The occurrence of springs within the level bottom of the Red River valley is extremely rare. The water seeping under

Northern Pacific Bridge, Between Fargo and Moorhead, Showing Flood of 1897.

Island Park, Fargo, Showing Flood of 1897.

the heavy lacustrine clays from the regions along the borders of the valley are effectually held down by the impervious clay, so that what would otherwise break forth as springs is now held in confinement, furnishing water for the tubular and Pleistocene artesian wells, where the restraining clay is penetrated in drilling. As the river valleys become deeper by erosion, springs break forth from the banks bounding the valleys, the waters being conveyed to the surface along the horizontal layer of porous gravel and sand. Such springs now exist in the deep valleys of the Red River of the North, and in the deep valley of the Sheyenne before it debouches upon the level plain of the bottom of Lake Agassiz above its own delta. Springs occur upon the level plain of the Red River valley, sometimes due to the hydrostatic pressure from the surface waters penetrating the ground upon higher land, which causes the soil water table to rise to the surface of the ground. A notable instance of this kind occurs along the front of the Sheyenne delta where crossed by the Fargo & Southwestern branch of the Northern Pacific railway at Woods station. Here a springy tract is caused by the waters which soak into the sandy soil of the Sheyenne delta and rise to the surface a few miles east upon the level plain which borders the delta.

Wells.—The conditions upon this area therefore render the problem of an adequate water supply from wells one of the greatest importance, since the sole dependence for the great majority of farm residents, as well as those living in towns, for a supply for all purposes, must be from this source, save only that which can be caught upon the roofs of buildings and stored in cisterns (an amount barely sufficient for strictly household purposes). The supply for drinking and culinary purposes for the cities of Fargo and Moorhead is derived from deep wells. Nature has, however, dealt bountifully in supplying water from wells. While nearly the entire water supply, as has been shown, must be derived from wells, over considerable areas flowing wells can be obtained from shallow depths, and upon the whole district an inexhaustible supply of fairly good water can be obtained with but little lift in pumping.

The wells of this region may be grouped into four classes: (a) Shallow surface or seepage wells; (b) deeper bored or tubular wells, in which the water rises due to pressure from a head; (c) artesian wells deriving their water supply from sand and gravel beds in the

drift, called Pleistocene artesian wells, and (d) artesian wells deriving their water supply from the Dakota sandstone.

There are comparatively few wells of the first class, and they are of little interest either from a geological or an economic standpoint. They are of interest as showing the height of the soil water table, and the fluctuations in its level during seasonal changes. The water in such wells is often strongly alkaline and unfit for any domestic use. The waters of the shallow wells, however, differ greatly in quality even in wells separated by very short distances and differing but little in depth. This circumstance shows the variability of structure and character of the deposits from the melting ice sheet which constitute the bottom of the ancient Lake Agassiz. Frequently dug wells furnish water which is of good quality from a digging having a gravelly bottom. When however the water is derived from a vein which contains a mixture of clay the water is very likely to be of a very strongly alkaline character and may contain other unpleasant or injurious impurities. The examination of waters from wells having clay bottoms indicates that the sediments deposited upon the bottom of glacial Lake Agassiz contained alkaline and other substances which render the water impure.

Two exceptions to the general conditions regarding surface wells are worthy of note. These are in the depth and character of the water of the wells on the sandy area of the Maple ridge, which traverses the course of the Maple river in Cass county, and in the wells on the Sheyenne delta plain in Richland, Cass and Ransom counties.

Upon these sandy tracts surface wells from twelve to twenty-six feet deep occur, furnishing inexhaustible supplies of water of very excellent quality. The water is usually contained in sand or fine gravel, and is commonly soft, and is perhaps the most nearly pure of any water in this portion of the state.

These conditions are explained by the sand deposits which act both as reservoirs and filters for the waters which fall upon the surface as rain and snow. The clay which underlies the beach sand serves as a dish to prevent the percolation of the water to lower depths, and the general surface is so free from any drainage slope that the water is held in the sand reservoir of the beach. Similarly on the delta plain clayey layers occur in the deposit sufficient to make the downward percolation of the waters slow. The sands both

Flowing Well and Tanks, Red River Valley.

Flowing Well, One-half Mile North of Mooreton, Richland County.

Flowing Well, Chaffee Farm, Casselton Quadrangle. Depth 431 feet; 1,000 barrels; Section 33 Township 138, Range 53.)

Flowing Well One-half Mile North of Woods, Cass County.

Digging Well—Driving Pipe.

Flowing Well. Just Struck. Trott Farm, Casselton Quadrangle. (Depth 418 feet. Flow at first, 4,000 bbls. per day. Section 10, Township 140, Range 53.)

of the beach and the delta were effectually washed by the waters of the lake during the time of their deposition, and thus were rinsed of the soluble salts such as impregnate the drift and lacustrine deposits generally.

Tubular Wells.—Tubular wells are common over nearly all parts of southeastern North Dakota, and furnish probably three-fourths of all the water used by the inhabitants for all purposes. By a tubular well is meant one made by boring with an auger, tubes thus made ranging in diameter from two to thirty inches. Frequently, however, a digging is made with a spade to a depth of twelve to thirty feet, and then an auger is used to penetrate deeper till the water bearing vein is reached.

Tubular wells range in depth from twenty to 200 feet, and the water often rises to within two to eight feet of the surface of the ground, and sometimes stands even with the surface. A generalized section of a boring for a tubular well would show black soil from two to eight feet from the surface, followed by stratified dark silt layers to a depth of thirty to seventy feet, and below boulder clay or till. The bottom of the drift is generally reached at depths not exceeding 200 feet from the surface, though the horizon between the drift and the shale cannot always be clearly distinguished owing to the similarity between the boulder clay and the shale-clay.

Sometimes the tubular wells derive their water supply from layers of sand in the lacustrine deposits, sometimes from gravel and sand at the horizon between the lacustrine silt and the till, sometimes in gravel and sand strata in the till, and again the vein may be struck at the bottom of the drift, while not infrequently the driller reports penetrating the "soapstone," the drillers' term for the Cretaceous shale-clay, before any water bearing vein of sufficient amount is struck.

From whatever horizon the water is derived, however, the same general conditions prevail determining the behavior of the water, viz., a compact and impermeable layer or bed of clay overlying the water bearing stratum, no sign of water appearing until the bottom of this clay is reached. The water rushes up the tube often with considerable force, and it is reported on good authority, in wells in which a digging had first been made and a hand auger used for the deeper boring, that it is sometimes with difficulty that the well digger is able to avoid being drowned before he could be lifted out of the

well. The supply of water is practically inexhaustible, it often being impossible to lower the water in the tube or digging to any appreciable extent even with the use of a wind mill or steam pump. Sometimes the water can be lowered appreciably by pumping, the water resuming its original height in the well within a short time after pumping ceases.

Pleistocene Artesian Wells.—It will be observed that the difference between the so-called "tubular" wells, in which the water rises nearly or quite to the surface of the ground, but does not actually flow, and an artesian well of the Pleistocene class, in which the water flows over the top of the tubing, is one of difference in the lifting pressure or head merely. Every gradation in head can be seen in the wells in this region, from those in which there is very little rising of the water in the tube but into which the water enters very readily, through the different heights to which the water is elevated in the tube to the flowing well in which there is a flow sustained by good pressure.

In the northern part of Cass county flowing wells are obtained at depths ranging from forty to 200 feet.[*] There are also a few wells in the southwestern portion of Cass county in Davenport and Leonard townships, belonging to this class which range in depth from thirty to 175 feet. These wells do not flow with strong pressure, and the flow is subject to weakening. Such wells in some cases have ceased to flow entirely and have to be pumped. It is likely that in many cases the cessation has been due to faulty construction in the well tubing or to infiltration of sand, and not to any real loss of pressure due to the head.

A well in section 28, Davenport township, at a depth of eighty feet, yielded a strong flow of nearly 1,000 barrels when first drilled. Two wells in the northern part of the same section are respectively eighty-seven and 120 feet, both of these yielding only light flows. One of these, that at eighty feet, has ceased to flow and requires to be pumped. Another in the southeast corner of section 20 yields a small flow, and also one at 113 feet in section 34, a small stream. In section 11, Leonard township, a light flow was obtained from a depth of 101 feet, and in section 3 one at 175 feet, a quite vigorous flow was at first obtained, but soon became very light, furnishing an amount barely sufficient to supply the household and farm demands.

Flowing Well, Staples Farm, Casselton Quadrangle. (Depth 514 feet; Section 12, Township 140, Range 53.)

Same with Gauge Closed.

Lakes Formed from Staples' Well.

anks for Storing Water from Artesian Well of Light Flow. (Near Casselton, Dalrymple farm.)

Budke Well, Southwest of Wheatland. (Showing sand which has been thrown out of the well.)

Flowing Well, Thirty Feet Deep, Red River Valley.

These wells vary not only in the depth at which water is obtained, but also in the quality of water. In most cases the water is of fairly good quality for general purposes, and is not infrequently soft and suitable for laundry purposes. In none of these wells is there the characteristic saltiness which is uniformly present in the deeper artesian wells in which the supply is obtained from the Dakota sandstone. Shallow artesian wells also occur at a few places in Buffalo township, Cass county.

The Source of the Water.—The source of the water in these shallow flowing wells, like that of a great number of tubular wells in the district, is in beds of glacial gravel and sand. The great variation in the depth of these wells within short distances indicate that the veins which are the sources of the water are not only of different depths, but that these lie in comparatively narrow zones or belts, rather than in broad, widely extended sheets. A variation in depth between forty and 134 feet within a distance of less than two miles in the area of flowing wells in southeastern Cass county; three flowing wells having depths of 100, 125 and 145 feet, all within the area of one section in Spring Prairie township, Cass county, indicate distinct and separate reservoirs from which the water supply is derived in each case. Similar figures showing marked variation in the depths of the water veins in tubular wells where the water in each case rises within a few feet of the surface of the ground, but does not flow, are similarly explained. Four wells in section 34, Elmwood township, are respectively 90, 110, 117 and 201 feet in depth, and the water rises respectively to within four, nine, ten and sixteen feet of the top of the ground. Similar diversities in depth characterize the whole area.

It has frequently been observed that in the excavation or boring for a second well within a few rods or even a few feet from one which had furnished an abundance of water, but which had choked with sand or otherwise become disused, a thinner gravel or sand vein was encountered at about the same depth as the water bearing vein in the first well, but no water or but a scant supply was obtained. Sometimes no trace of such a vein as that which yielded the water in the first well was found in the second boring. It seems, therefore, that the gravel or sand veins are not continuous over large areas, and that they thin rapidly and cease altogether. It would seem, however, from the abundant supply of water and the strong

head in most of the tubular wells, and the Pleistocene artesian wells, that the veins extend for considerable distances along some line of direction.

The higher lands outside the limits of the Red River valley where frequent sandy and gravelly tracts occur, and where the surface drift is often loose and porous in texture, furnish a suitable gathering ground. Here the water falling as rain penetrates the porous soil and is conducted through the gravel beds to the lower levels. The preglacial valley in which Lake Agassiz existed formed a basin or trough in which the glacial materials were deposited from the ice sheet, and it is thus that porous tracts of gravel and sand may be so placed as to afford conduits or underground channels to convey the water which penetrated the grounds upon the higher lands outside the valley to the lower levels beneath the surface of the lake floor. The compact and impenetrable clay above and below the porous sandy or gravelly layers serves to effectually prevent the dispersion of the waters, and thus when a vertical boring from the level lake floor penetrates through the compact clay into the saturated sands and gravels the water in these layers immediately rises in response to the simple hydrostatic principle.

Some borings are recorded which penetrate to the bed rock, and no considerable amount of water was obtained. This is explained by the narrow areal extent of the water bearing layers, such borings having penetrated no veins of gravel or sand of such extent as to contain any large amount of water.

Wells of the Dakota Artesian Basin.—The western two-thirds of the Casselton quadrangle lies within the Dakota artesian basin. On this part of the quadrangle strong flows are obtained at depths ranging from 250 to more than 500 feet. The water is obtained in all cases from a fine-grained sand of loose texture. It is generally conceded that the formation from which the water is obtained is the Dakota formation.

The water in these wells is generally salt and not suitable for irrigation purposes, though it is not found to have any injurious effects upon animals that drink it, and it is quite agreeable to the taste after it has become habitual. The water is often not as hard as that obtained from the more shallow Pleistocene flowing wells, or the tubular wells.

The wells vary considerably in depth. This seems to be due to the occurrence of alternating layers of sandstone and shale, in some cases a sufficient flow being obtained in the first sand, and in other cases the second sand layer being penetrated, and not infrequently more than one water bearing vein is struck in the same boring.

In section 10, Walburg township, Cass county, two flowing wells about forty rods apart are respectively 265 and 440 feet in depth. Four miles north, in section 26, Gill township, water was obtained first at 362 feet, but insufficient in amount, and another flow in the same boring was struck at 405 feet.

In section 32, Amenia township, Cass county, two flowing wells one-fourth mile apart are respectively 350 and 450 feet deep. Five miles southeast, in section 21, Casselton township, two veins from which water flows over the surface of the ground were struck at 360 and 425 feet respectively. In the southeastern part of Walburg township, within a radius of one mile, occur five flowing wells at depths respectively of 240, 414, 430, 434 and 460 feet.

The granite bed rock has been struck in four places near the eastern edge of the Casselton quadrangle, at depths of 411, 460, 470, and 475 feet respectively, and very little water, or none at all, was obtained. The records of these borings so far as obtainable do not show the occurrence of the characteristic water bearing Dakota sandstone.

The pressure of the wells of the Dakota artesian class increases toward the west in this district. In the zone of the shallower wells of this class, those having depths ranging from 200 to 300 feet, the pressure is not great, and the water is generally not able to be conducted more than five or six feet above the surface of the ground. As the depth at which the water is obtained becomes greater toward the west, the pressure of the water becomes greater. In about the center of the Casselton quadrangle is a zone in which the calculated height to which the water might be carried, as determined from the well pressures, is 1,000 feet above sea level, or about fifteen to twenty feet above the surface of the ground. The 1,000-foot contour traverses nearly centrally the zone of wells of 300 to 400 feet in depth. Another contour line representing a height of 1,100 feet above sea level traverses nearly midway the zone of wells of 400 to 500 feet in depth, and lies about five to six miles west of and nearly parallel with the 1,000-foot contour. The height of the land

surface above sea level in this zone averages about 1,060 feet, giving a lift of the water above the surface of approximately fifty feet. From three to five miles west of this contour is another marking the 1,200-foot elevation above sea level, this contour traversing the territory which lies adjacent to the Red River valley, but beyond the area covered by the waters of Lake Agassiz. This contour in a general way runs parallel with the 1,100-foot and the 1,000-foot contours. The calculated height to which the well pressure would carry water in this region is from fifty to nearly 100 feet above the surface of the ground.

THE WATER SUPPLY OF THE TOWER QUADRANGLE.

By H. V. Hibbard.

Description of the Area.—The region included under the present discussion is approximately twenty-four miles wide and thirty-five miles long, its greater extent being from north to south. The northern boundary is about five miles north of and parallel with the Northern Pacific railway between Buffalo and Valley City. The western boundary runs through Valley City and follows nearly the course of the Sheyenne valley southward. The southern boundary runs east and west about one and one-half miles south of Fort Ransom.

A part of each of three counties make up the area of the Tower quadrangle. A portion of the northern part of Ransom county occupies the southern one-fourth of the quadrangle. The eastern third of the remainder is the southwest corner of Cass county. The southeast corner of Barnes county fills out the rest of the area.

The Water Resources.—As a fact of general interest under this subject it may be stated that since the annual rainfall is about twenty inches, and the rate of evaporation for the same time is about twenty-five inches, the only available supply of water, except that from artesian wells, is that which soaks into the earth and is retained in reservoirs of porous sand and gravel.

In considering the surface waters mention should be made of the streams both intermittent and constant, the lakes, undrained sloughs and ponds and springs.

Only one of the valleys or watercourses noted above bears a perennial stream, and that is the Sheyenne valley.

The Sheyenne river is a sluggish stream with many windings in the flood plain of its valley, about twenty feet wide, from a few inches to three or four feet deep, with steep mud banks, and flowing with a fall of one and one-third feet per mile. From Valley City south to Oakville it flows through a shale or gumbo region, having trees and shrubs only bordering its immediate banks. From Oakville to Fort Ransom and below the tree vegetation spreads farther out over the flats adjoining the river, and up the steep sides of the valley and penetrating the coulees but leaving off abruptly before reaching the prairie land beyond. During the rainy season this quiet river becomes quite a torrent sweeping across the intervening points between the bends but never reaching the second flats or cultivated bottoms above.

The Maple river is an intermittent stream. Its valley is dry throughout the greater part of the year except for sloughs and ponds of stagnant water which occur at intervals along its course.

Springs. — Springs occur along the valley of the Maple river and the Sheyenne and their tributary coulees. Usually the water from this source is usable, being free from alkaline and saline salts which contaminate the water from many shallow wells. Considering the living springs and those which may be uncovered by a little excavation this source of water supply is important, especially in the Sheyenne valley in the southwestern part of the quadrangle. A spring is merely a leak or emergence of the underground waters back to the surface. The general conditions necessary, therefore, for the development and maintenance of a spring are a sufficiently large gathering area, a subterranean reservoir consisting of a sufficiently porous and extensive stratum which outcrops in the surface or is connected with it by means of an impervious layer along which the water may flow.

The gathering area in this instance is the upland prairie bordering the Sheyenne or Maple rivers. The mixture of clay, sand, gravel and boulders, the so called drift, overlies the bed rock of shale of this region to a depth of about 100 feet. Throughout this drift, sand and gravel strata, and especially the terraced or shelf like deposits on the valley sides, occur. These then furnish ample store room for the collection of rainfall, and the impervious clay of the same drift or the shales beneath provide a floor for retaining the water and along

which they find their way to the outcrop on hill side or valley slope.

Sloughs and Ponds.—The landscape features which impress themselves upon the notice of the wayfaring man especially during the wet season are the ponds, sloughs and marshes. They are everywhere. Even in the immediate vicinity of the water courses they crowd up to the very banks. Here indeed one would expect the stream to turn aside or send a heading tributary back into and drain the ponds near by. But as before mentioned the valleys seem to be laid out without any reference whatever to the task of carrying away the surplus surface waters. As a matter of fact there are no modern or recently formed channels. The valleys and water-courses here formed were produced by the water flowing from a great sheet of melting ice which once overspread the entire prairie during the period in geological history known as the Ice Age.

As the dry season advances these surface waters rapidly waste away by evaporation. Only the deeper depressions retain a permanent supply; those whose depths reach below the permanent subterranean water level.

Subterranean Water. — The wells of this quadrangle, although varying greatly in depth, obtain their water supply from three different horizons corresponding to the rock structure underlying the region. The bed rock consists of shale or what is variously called "slate," "soapstone" or "hard pan." It is a clay formation, white or dark blue in color, and of fine texture and arranged in horizontal layers. Overlying this slate is a mantle or covering of what is called "drift," a mixture of clay, sand, gravel and large stones. The thickness of this mantle rock varies from a few inches to 150 feet. Over by far the greater part of the region the drift may average eighty feet in thickness. The greater number of wells reach water before penetrating this drift formation. The second water horizon lies in the shale or slate stone beneath the drift. The third horizon is that from which the artesian water is obtained and lies at a depth of from 400 to 600 feet.

In considering the wells of the first horizon, or those which do not penetrate the drift and enter the shale below, one finds great variation in the composition and arrangement of the components of the rock mantle passed through in order to reach water. Although this lack of definite order prevails a few general statements may be

made that hold good when a large number of well records are examined. As much as 75 per cent of the mantle rock of the eighty to 100 feet before noted is clay made up of the varieties yellow, blue and stony, but not generally hard or very tenaceous, there being a sufficiently large constituent of sand intermingled to make it light or easily worked. The remaining 25 per cent is made up of sand, quicksand and gravel. This is distributed through the clay in lenticular masses and layers varying from a few inches to several feet in thickness. This stratification of the lighter materials of the drift mantle though not generally horizontal in position are never pitched at very high angles. Where these layers of sand and gravel have considerable extent and thickness the more copious and better qualities of water are found. In general the following arrangement seems to be met with under average conditions: First ten to forty feet yellow stony clay with interspersed strata of sandy or gravelly composition, then blue clay also containing sand and gravel prevails until the bed rock or slate is reached. While this arrangement holds fairly good throughout the greater part of the quadrangle a few notable exceptions should be mentioned. These are the valleys and coulees of the Maple and Sheyenne rivers, the bluffs of the Sheyenne from Valley City to Oakville and the "Sand Prairie" region of Bear Creek and Oakville townships. In the Maple and its branches coarse sand and gravel with very little clay is found generally through the upper ten to thirty feet. Sand Prairie wells almost never penetrate clay but show stratified layers of coarse and fine sand. The water supply of the Sheyenne valley above noted belongs to the second water bearing or shale horizon, there being no mantle of drift material in that area. The quality of the water derived from this upper or drift horizon is variable, that from shallow wells, is frequently more or less alkaline, being obtained from surface wash or catchment basins of slight depth where alkaline salts have been lodged by upward seepage and subsequent evaporation of soil water. Water derived from the deeper wells in the blue clay, and especially those that reach the bottom of the drift near the underlying shale formation, are also liable to contamination from alkaline minerals. In general the best water especially for household use is that found at intermediate depths in the yellow clay or extensive sand and gravel layers. Regarding the distribution of the wells of the drift mantle over the eastern

three-fourths of the quadrangle a fairly constant relation holds between the depth of the wells and the topography.

Two ranges of townships, 55 and 56 west, those through which the Maple river flows, and the range adjoining on the west, may be considered as a zone of shallow wells. The average depth to an abundant water supply here lies between 30 to 60 feet. On the Alta ridge, range 57 west, the average depth of wells is about three times as great. A narrow strip along the eastern side, as far south as Eldred township, contains wells at considerable depths when compared with the Maple region immediately west. Continuing southward into Highland and Sheldon townships, good water but not an abundant supply for stock purposes, is found at slight depth of 20 to 40 feet. Another region of shallow wells, good and abundant water, is Sand Prairie in Bear Creek township. As before mentioned stratified sand and gravel constitute the structure to a depth of 40 to 60 feet. Being nearly surrounded by higher land, a large catchment area insures abundant supply, while the sand and gravel affords an extensive reservoir uncontaminated by any impurities. Not a few wells seven feet in depth supply good and abundant water.

In the clay region adjoining between Sand Prairie and Fort Ransom, water is reached with greater difficulty, and the supply and quality is somewhat uncertain.

From section 3, Oakville township, northward to Valley City in the vicinity of the Sheyenne, the quality of the water in general is distinctly and decidedly bad. Water here, either from shallow or deep wells, all in the shale rock, is charged more or less with salty and alkaline substances. For cattle and horses this water is available, but the human being not inured to such potions would best remain thirsty.

In the neighborhood of Valley City, northward four miles and eastward to the slope of Alta ridge, good water and an abundant supply is found from 25 to 50 feet in depth. The surface is a sandy loam underlaid by 25 feet of yellow clay, then follows blue clay with interbedded sand.

Regarding the water supply from what here has been called the second or shale horizon, little need be said. Usually water found under such conditions is scanty and not suitable for general use. It is surcharged with alkali and salt derived from the shale. A fair type of well in this horizon is one in Norman township, 138 N., R.

57 W., where the drill entered shale at a depth of 150 feet and the well was continued to a depth of 250 feet. Here a very slight amount of water was found and of bitter and alkaline taste.

Artesian Basin. — Throughout the eastern half of the quadrangle artesian water has been reached at a depth of from 400 to 600 feet. So far as present indications go it is safe to say that the artesian water yielding stratum lies at about the above depths under the entire area. Artesian wells are needed especially in the northern part of the quadrangle, and could doubtless be obtained if borings were made to the proper depth.

The quality of the artesian water so far obtained is fairly constant. The temperature is considerably higher than that of the shallow wells. It always contains the mineral compounds of salt, magnesia, alkalies, iron and sulphur, and these generally in sufficient quantity to impart a distinct taste to the water.

WELL RECORDS OF THE

(From the field notes of H. V.

Reference*	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 65	NW	19	136, 57	Preston	18	10
Page 64	NW	12	135, 57	Springer	33	16
Page 55		21	140, 58	Valley	30	10
Page 65	NE	16	140, 58	Valley	50	15
Page 65	SW	22	140, 58	Valley	23	18
Page 65		21	140, 58	Valley	45	25
Page 66	SW	21	140, 58	Valley	50	25
Page 66	SE	22	139, 58	No name	28	
Page 66	River bottom	34	139, 58	No name	40	
Page 66	S½ of SE	35	139, 58	No name	4	Flows
Page 66	E½ of NW	22	140, 58	Valley	14	10
Page 66	NW	18	138, 57	Norman	176	
Page 68	SE	30	138, 57	Norman	250	
Page 69	SE	10	139, 57	Cuba	107	
Page 70	E½	6	138, 57	Norman	50	
Page 70		18	138, 57	Norman	120	
Page 70	SW	28	139, 57	Cuba	90	
Page 71		14	138, 58	No name, near Daly		
Page 71	E½	4	136, 55	Liberty	27	18
Page 71	SE	4	136, 55	Liberty	470	Flows
Page 72	SW	34	139, 55	Hill	500	Flows
Page 73	SE	28	138, 55	Clinton	19	10
Page 74	SE	11	137, 56	Rariton	749	Flows
C62, 45	NE	24	137, 57	Thordenskjold	64	
C63	SE	24	137, 57	Thordenskjold	70	
C65, 45	E½	25	137, 57	Thordenskjold	57	
C66	SW	30	137, 56	Rariton	72	
C68	NE	30	137, 56	Rariton	68	
C70	SE	34	137, 57	Thordenskjold	87	
C71	SW	26	137, 57	Thordenskjold	85	40
C69	SE	33	138, 55	Clinton	31	10
D4, 51	SW	26	138, 56	Binghampton	15	5
	NW	26	138, 56	Binghampton	15	6
	E½	22	138, 56	Binghampton	22	
	SE	14	138, 56	Binghampton	23	7
	NE	14	138, 56	Binghampton	42	
					40	
	SE	2	138, 56	Binghampton	19	
		4	138, 56	Binghampton	33	15
D18, 53	NE	8	138, 56	Binghampton	30	17
D83	NW	17	138, 55	Clinton	33	
D86	SW	5	139, 55	Clinton	50	

* References are to pages and paragraphs in Field Note Books.

TOWER QUADRANGLE

Hibbard and Daniel E. Willard.)

Yield	Character of Rock	Character of Water	Remarks
Plenty............	2 soil; 16 gravelly sandy clay......................	Good............	This is 30 ft. above river surface.
Plenty............	Soil 3 9 ft. yellow clay; 21 ft. blue (shale) clay	Good............	12 to 15 ft. above river level.
Plenty............	6 ft. soil; gravel 24 ft.......	Good...........	
Plenty............	All clay; brown gumbo....	Bitter alkali, bad	In North Valley City.
Plenty.	Blue clay (sticky).........	Good............	15 or 20 ft. above river level.
Plenty............	"Black soil" clay 20 ft.; 10 ft. gravel; 5 ft. blue clay.	Good............	On terrace 6 blocks NW. "Kindred Shale" at 45 ft. in Valley City.
Plenty............	All gravel.................	Good............	In Valley City gravel terrace.
....	Soil 6 ft ; 22 gravel........	Good............	60 rods from river.
Plenty............	All gumbo	Alkali............	Down on river bottom.
Abundant........	Gravel bank, shale at bottom.....................	Good............	A good spring.
Plenty	Sandy loam...............	Good............	Valley City near R. R. bridge, first terrace 15 ft. above river level.
Slight.............	30 ft. yellow clay till; 115 blue clay; 15 ft. sand; 3 ft. hard pan; 10 blue clay; 2 hard pan; 1 ft. gravel and slate.........	Good............	I think drift was passed at about 80 ft. here.
None..............	Yellow clay 12 ft.; blue clay 138; "soapstone" at 150 ft.	....	This shows drift 150 ft. here.
....	No shale or soapstone; blue clay in bottom...........	....	Drift mantle here over 107 ft.
Plenty............	2 ft. soil; 16 ft. yellow clay; 32 stony blue clay.......	Good............	A well ½ mile E. of this is 90; no shale; all drift.
....	120 clay, drift, just into shale...	....	Penetrated drift to shale.
....	90 ft. drift to shale.........	Good............	Drift here 90 ft.
....	....	....	Good springs in this section.
Plenty............	Soil 8 ft,; clayey sand 8 ft.; gravel 2 ft.; 9 ft. blue clay	Good............	At Enderlin in Maple valley in alluvial deposits to shale.
Large	Rock record no good......	....	A good flow at 225 ft.
1,410 bbls. per day	Stony clay to 200 ft.(?) then shale to bottom..........	Soft saline, good.	Strong flow brings up fragments of shale. Mr. Card's well.
Plenty............	Loam 2 ft.; 17 ft. sand and gravel.............	Good............	On "first" terrace in Coulee of Maple river ∴ gravel train.
Big...............	"First 100 ft, difficult drilling on account of stone; ∴ drift. Mr. P. Little, Prop....................	Good............	Meagre record; nobody knew.
Scant			
....	Gravel at bottom		
Plenty............	Sand at bottom		
Scant.............	Gravel at bottom.........	....	Bored; 28 inch hole.
Scant.............	Gravel and quicksand at bottom.	....	Bored.
Plenty............	Gravel and sand; soapstone at 150.......	. . ..	Bored; 32 inch.
....	.. ..	....	Bored.
Plenty............	Sand and gravel.		
....			
....			
....	Blue clay; quicksand.....	Good	
....			
....			
Plenty............			
Plenty............	Blue clay gravel bottom		
Plenty............	Glravel bottom		
Plenty............	Blue clay and gravel		
Plenty............	Gravel and sand at bottom	Good	
Plenty			

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
D92	NE	30	139,55	Hill	20	
	SE	19	139,55	Hill	40	
	SE	20	139,55	Hill	51	35
	SE	18		Hill	45	
E1, 68	NW	31	140,54	Buffalo	28	
E2	SE	1	139,55	Hill	60 to 225	
E9, 70	SW	4	139,55	Hill	48	25
			139,55	Hill	60	20
E15, 71	N½	35	140,56	Oriska	22	
	NW	34	140,56	Oriska	26	3
	SW	30	140,56	Oriska	20	6
			140,56	Oriska	46	
E17, 72	SE	25	140,57	Alta	25	
		35	140,57	Alta	92	70
		34	140,57	Alta	42	
E24, 73		32	140,57	Alta	125	10
73		31	Lanona	Alta	10	5
E27, 74		6	139,57	Cuba	36	
E30, 74			139,57	Cuba	40	3
E31	SE	6	139,57	Cuba	35	
E33	NW	8	139,57	Cuba	90	
E34	NW	9	139,57	Cuba	120	60
E38	NE	2	139,57	Cuba	100	16
E49, 79	SW	20	139,57	Cuba	270	
	NW	20	139,57	Cuba	80	
Page 74		31	137,55	Pontiac	50	25
Page 88	SE	31	137,57	Thordenskjold	96	70
Page 25, B. 23	SW	28	137,54	Highland	42	25
Page 26, B. 25	SW	32	137,54	Highland	32	20
Page 26, B. 26	SE	14	137,55	Pontiac	48	25
Page 27		18	136,55	Liberty	80	
Page 30	SE	34	136,55	Liberty	36	25
Page 30	NE	26	136,56	Moore	50	30
Page 31, B. 40	NW	11	135,57	Spring	28	
Page 34		10	135,57	Spring	40	30
Page 34	NW	17	135,55	Casey	50	30
Page 34	SE	8	136,55	Liberty	50	40
Page 85, B. 44	NW	18	136,55	Liberty	80	50
Page 36, B. 47	NW	1	135,56	Fuller	35	15
Page 37	SW	1	135,56	Fuller	36	20
Page 38, B. 50	NW	3	135,57	Springer	66	40
Page 39	NE	7	135,57	Springer	70	
Page 39	NE	7	135,57	Springer	35	
Page 40, B. 52	SW	24	135,58	Ft. Ransom	224	30
Page 40, B. 53	NW	23	135,58	Ft. Ransom	60	40
Page 40	NE	16	135,58	Ft. Ransom	20	14

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty...........	....	....	Dug.
Plenty...........	Blue clay.		
Plenty...........	Gravel at bottom.		
Plenty...........	Gravel and quicksand.		
....	....	Alkali...........	Wells drilled here 150 ft.; water bad; alkali.
Scant............	Blue clay.................	Hard...........	
Plenty...........	....	Poor.	
....	Quicksand at bottom......	Good.	
....	Gravel at bottom..........	....	Dug.
Plenty.			
Plenty...........	Gravel....................	Good.	
....	....	Good.	
Scant.			
....	....	Good; hard.	
Plenty...........	....	Poor.	
Plenty...........	....	Good.	
Plenty...........	Sand.		
Plenty...........	....	Good.	
....	Gravel.		
Plenty...........	Dug 75; clay..............	Alkali...........	3 ft. diameter.
Scant.			
Plenty...........	Gravel, 20 ft.; blue clay, 5; quicksand, 25...........	Good...........	In side of Maple coulee. Summary of wells NE. Valley City on tower sheet: 25 to 50 ft. deep; blue clay at 25 ft.; water abundant, good; yellow clay 25 ft.
Plenty...........	Sandy soil, 3 ft.; yellow clay, 10 ft.; blue clay, 80; gravel, 3 ft............	Good...........	Strong ground, morainic in vicinity.
Plenty...........	Clay (yellow), 20 ft., blue clay, 20 ft.; gravel, 2 ft..	Good...........	In Maple coulee.
Plenty...........	Sandy loam, 8 ft.; sand, 4; gravel, 4; blue clay, 14 ft.; coarse cobble, 2 ft.; clay with coal masses scattered thru it: this is carbonized wood of drift origin..........	Good...........	In bottom of Maple coulee
Plenty...........	47 ft. clay till; 1 ft. shale...	Good.	
....	Shal at bottom.....	....	Drift 80 ft. thick.
Plenty...........	Clay 30 ft.; blue clay, 3 ft.; quicksand 3 ft.......	Good.	
Scanty...........	No clear record.		
....	Clay (yellow, stony), 12; blue clay, 12; gravel, 4..		
Plenty...........	Soil, 4; clay, 8; clay and sand, 28................	Good.	
Plenty...........	40 ft. clay drift; 10 ft. coarse sand..............	Good...........	Well bored at Buttzville.
Plenty...........	48 ft. clay drift; 2 ft. gravel.	Good.	
Plenty...........	60 ft. till.; 5 ft. gravel; 15 ft. hard blue clay, shale perhaps.............	Good.	
Plenty...........	Soil, 2 ft.; yellow clay, 24; sandy blue clay, 8 feet; coarse gravel, 1 ft......	Good.	
Plenty...........	Soil, 3 ft.; sandy red clay, 6 ft.; blue clay, 25 ft.; 2 ft. gravel..........	Good.	
Scanty...........	Soil, 2 ft.; hard pan clay, 64 ft................	Good.	
....	70 ft. stony clay drift.....	....	No water.
....	35 ft. coarse gravel........	....	In coulee bottom.
Scanty...........	2 soil, 50 ft. stony clay, 172 blue clay not stony..	Good...........	Indicates drift 50 or 60 ft.
Plenty...........	Soil 3 ft., 7 ft. yellow clay, blue clay 50............	Good.	
Plenty...........	All sand..................	Good...........	On moraine.

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 41, B. 57	NE..........	8	135, 58	Ft. Ransom..........	15	....
Page 41, B. 58	SW..........	9	135, 58	Ft. Ransom..........	20	....
Page 43, B. 59	NE..........	32	135, 58	Ft. Ransom..........	14	....
A52..........	NW..........	8	140, 55	Tower..........	70	50
B32..........	SE..........	32	137, 54	Highland..........	515	Flows
B32..........	NW..........	19	139, 54	Howes..........	85	....
A29..........	SW..........	4	140, 56	Oriska..........	37	....
A38..........	NW..........	8	138, 55	Clinton..........	40	20
A64..........	NW..........	20	141, 54	Ayr..........	28	18
A66..........	E½..........	34	141, 54	Ayr..........	117	95
A1..........	NW..........	18	140, 55	Tower..........	32	10
A13..........	....	11	140, 55	Tower..........	30	Flows
A14..........	SE..........	15	140, 55	Tower..........	48	Flows
A16..........	SE..........	13	140, 55	Tower..........	606	Flows
	SE..........	4	137, 54	Highland..........	500	Flows
B18..........	E½..........	8	137, 54	Highland..........	30	20
Page 49..........	SE..........	12	135, 58	Ft. Ransom..........	44	25
Page 49..........	SW..........	2	135, 55	Ft. Ransom..........	156	....
Page 49..........	NW..........	2	135, 55	Ft. Ransom..........	170	....
Page 49..........	NW..........	5	135, 57	Springer..........	96	30
Page 58..........	....	7	135, 57	Springer..........	100	....
Page 58..........	....	8	135, 57	Springer..........	100	....
Page 58..........	....	5	135, 57	Springer..........	....	....
Page 58..........	SW..........	28	136, 57	Preston..........	175	....
Page 59..........	....	8	136, 57	Preston..........	180	....
Page 59..........	NW..........	18	136, 57	Preston..........	14	8
Page 60..........	SE..........	2	135, 58	Ft. Ransom..........	56	40
Page 60..........	NW..........	2	135, 58	Ft. Ransom..........	105	....
Page 60..........	NW..........	25	136, 58	Bear Creek..........	10	6
Page 60..........	NW..........	13	136, 58	Bear Creek..........	41	25
Page 60..........	NE..........	14	136, 58	Bear Creek..........	40	20
Page 61..........	NE..........	14	136, 58	Bear Creek..........	25	16
Page 61..........	....	26	137, 58	Oakville..........	50	30
Page 62..........	NW..........	3	136, 58	Bear Creek..........	34	24
Page 62..........	SE..........	1	135, 58	Ft. Ransom..........	30	20
Page 55..........	SE..........	12	135, 58	Ft. Ransom..........	22	....
Page 55..........	NE..........	12	135, 58	Ft. Ransom..........	70	23
Page 56..........	NE..........	12	135, 58	Ft. Ransom..........	40	16
Page 57..........	NW..........	18	135, 57	Springer..........	22	10
Page 2, A3..........	NE..........	6	139, 54	Howes..........	200	....
Page 3, A8..........	NW..........	5	138, 54	Eldred..........	70	30
Page 3..........	SE..........	4	138, 54	Eldred..........	....	Flows

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty	Clay and sand mixed	Soft, good.	
Plenty	All hard clay	Good	
Plenty	Sand and gravel; blue clay at bottom	Good.	
Plenty	Clay 68 ft.; quicksand 2 ft.	Slightly alkaline; good	Dug 45 ft; drilled 25 ft.
	No record	Alkaline; salty.	
Abundant	Till., 65 ft.; sand, 10 ft.	Good.	
Light	Sandy clay	Good.	
Plenty	Clay, 30 ft.; sand, 10 ft.	Good	Land gently rolling.
Plenty	Clay, drift	Slightly alkaline.	
Plenty	Yellow clay, 25 ft.; blue clay, 25 ft.; blue clay and sand, 67 ft.	Good	Wells within two miles, 40 ft. deep, give abundant and good water.
Abundant	Clay, 22 ft.; blue clay, 10 ft.	Alkaline.	
	Drift	Good.	
Abundant	In bottom of Maple coulee	Good	A two-inch stream rises 10 ft. above ground.
Abundant	150 ft. clay; 10 ft. hard pan; 446 ft. black clay	Good	Character of rock, record not reliable. Senator Talcott's well.
	No record	Alkaline; bitter.	Boyle well.
Plenty	In drift	Good.	
Plenty	Yellow clay, 15 ft.; 29 ft. blue slate	Salty	Usable.
	40 ft. clay and stony gravel; 116 ft. shale		
	45 ft. yellow clay; 130 ft shale.		
Slight	20 ft., gravelly clay; 12 ft., sand; 12 ft. sandy clay; 46 ft. slate; 6 ft. sand	Bad; alkaline	Not usable.
			This well passes into shale. At what point could not learn.
			Same as above.
			This section house abandoned; no good water.
Plenty	Clay; no shale(?)	Good	Bored 2-inch hole.
For house	Clay, 100 ft; 80 ft. red clay and gravel	Good.	
Plenty	Clay, 12 ft.; coarse gravel, 2 ft.		Good springs in valley here. Sheyenne river.
Plenty	Drift, 56 ft.	Good	Shale at bottom.
	Clay (stony), 100 ft.		Shale said to be within 100 ft. Improbable.
Plenty	All gravel	Good	On Sand Prairie.
Plenty	1 ft. soil; 5 ft. clay; 35 ft. sand	Good	On Sand Prairie.
Plenty	All clay	Good	Heavy soil, gently rolling land.
Plenty	Clay	Good	Heavy clayey soil; gently rolling.
Plenty	Clay	Good	45 ft. seems to be shale.
Plenty	Soil 2 ft.; sand and gravel.	Good	Sand Prairie; very level.
Not abundant	All clay (till)	Good	Gently rolling; overwash plain is indicated by sandy surface of topography.
Plenty	2 ft. soil, clay; 10 ft. yellow clay; 10 ft. blue clay.	Hard; good	In valley of Sheyenne, second terrace.
Plenty	Clay soil, 1 ft.; soft stony clay (till), 18 ft.; blue clay, hard, not stony (shale), 51 ft.	Good	On side of coulee, 60 ft. above river bed.
Plenty	20 ft. glacial drift; 20 ft. blue shale	Soft; good	In mouth of coulee, 60 ft. above river bed.
Plenty	In sandy, black alluvium; no shale	Good	12 ft. above river surface.
	Probably drift		
		Alkaline.	
125 barrels.			

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp & Range	Township	Depth	Height of Water
Page 3	SE	9	138,54	Eldred	565	
	SE	18	138,54	Eldred	115	60
Page 4, A15	NE	8	137,54	Highland	513	Flows
Page 4	W½	8	137,54	Highland	32	
Page 4	SW	6	137,54	Near Enderlin	40	
Page 6, A31	NW	24	136,55	Liberty	27	
Page 6	NW	18	136,54	Sheldon	23	
Page 8, A51		....	135,58	Ft. Ransom	35	
Page 9, A56	NE	5	135,57	Springer	90	
A61	SE	34	136,57	Preston	70	
A62	NE	2	136,57	Preston	53	
Page 10, A63	NW	2	136,57	Preston	53	
Page 10	NW	6	135,56	Fuller	32	
Page 10, A65	SE	30	136,56	Moore	40	
Page 10, A66	SE	6	135,56	Fuller	70	
Page 10, A67	NW	8	135,56	Fuller	46	23
		17	135,56	Fuller		
Page 11, A69	SW	8	135,56	Fuller	68	20
	NE	8	135,56	Fuller	40	
Page 13, A74	NW	9	135,56	Fuller	60	
Page 13, A79	SE	33	136,56	Moore	58	
Page 13, A81	NE	15	136,56	Moore	142	
Page 14, A82	NW	34	136,56	Moore	40	
Page 14, A83	SE	28	136,56	Moore	66	
Page 43, B61		34	136,58	Bear Creek	34	17
Page 44	SE	26	136,58	Bear Creek	12	5
Page 44	SE	22	136,58	Bear Creek	6	4
Page 44	NE	26	136,58	Bear Creek	68	15
Page 44	SE	23	136,58	Bear Creek	10	9
Page 44	SW	22	136,58	Bear Creek	50	
Page 46	W½ of SW	13	136,58	Bear Creek	25	
Page 46	NW	10	136,58	Bear Creek	28	
Page 47	SE	15	136,58	Bear Creek	28	
Page 48	SW	11	135,58	Ft. Ransom		Flows
Page 48	SW	12	135,58	Ft. Ransom	38	
Page 48	NW	12	135,58	Ft. Ransom	71	38
Page 49	SE	12	135,58	Ft. Ransom	44	
Page 49	SW	2	135,58	Ft. Ransom	156	
Page 49	NW	2	135,58	Ft. Ransom	170	
Page 49	NW	5	135,57	Springer	96	
Page 50	Center of	12	135,58	Ft. Ransom	42	
Page 50	NW	1	135,58	Ft. Ransom	42	20
Page 52	SE	28	136,58	Bear Creek	50	
Page 53	NE	30	138,58	Bear Creek	4	9
Page 53	SW	18	135,57	Springer		Flows
Page 53	SE	4	136,58	Bear Creek	30	3
Page 53	NE	3	136,58	Bear Creek	39	4
Page 54	NE	34	137,58	Oakville	32	3
Page 54	SE	29	137,58	Oakville	20	6

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
900 barrels.			
Fair	....	Alkaline.	
....	....	Salty.	
Good.			
....	20 ft. clay		
....	Clay, 25 ft.; quicksand, 2 ft.		
....	All sand		
Good	All drift	Good.	
Scant	....	....	Several wells similar in character; scant supply of water.
Scant	Drift.		
Plenty	Drift; gravel at bottom	....	Coal vein 1 ft. thick.
....	Drift; quicksand.		
Plenty	....	Alkaline.	
Plenty.			
Plenty	Drift.		
Spring.			
....	Gravel	Good.	
....	Gravel bottom.		
Plenty	60 ft. clay	....	Hardpan at 100 ft.
Plenty	Clay and blue clay.		
Plenty	Gravel and blue clay	....	Dug.
Plenty	Gravel, 4 ft.; 30 ft. blue clay	Alkaline; poor quality	Dug well.
Plenty	All quicksand	Good	Old flood plain of Sheyenne river.
Plenty	In clay	Good	Sand Prairie.
Plenty	Blue clay	Alkaline; salt.	
Plenty	Clay	Good.	
None	Blue clay.		
Plenty	All fine sand	Good.	
Plenty	Soil, 2 ft., sandy; sand, 24 ft	Good	Level; Sand Prairie.
Plenty	26 ft. clay; 2 ft. sand	Good	Gently rolling; edge of Sand Prairie.
Plenty	....	Good	Perennial spring.
Plenty	Sand, clay, gravel	Good	In alluvium of Sheyenne valley.
Plenty	4 ft. loam soil; 25 ft. gravelly clay; 1 ft. hardpan; 41 ft. shale	Bad; alkaline	On Sheyenne valley bottom.
....	15 ft. yellow clay; 17 ft. blue shale	Alkaline; salty.	
None	40 ft. clay and gravel; 116 ft. slate-shale	....	No water; so-called dry well.
....	45 ft. yellow clay and gravel; 125 ft. slate-shale		
....	20 ft. gravelly clay; 12 ft. sand; 12 ft. sandy clay; 46 ft. slate rock (shale); 6 ft. sand	Poor quality	Not usable.
....	20 ft. sandy clay; 22 ft. black clay; 1 ft. gravel ..	Very poor	Water unfit for any use.
Plenty	40 ft. clay (till); 2 ft. sand..	Good	At foot of hill in valley. In till from hillside wash.
Abundant	50 ft. till	Good	On moraine 1½ mile east of Sand Prairie.
Plenty	All in gravel	Good; hard	Level; Sand Prairie. Surface very stony.
Plenty	....	Good	A fine spring; water charged with iron.
....	1 ft. sandy soil; 29 ft. fine sand	Good	Level; Sand Prairie; dug well.
Plenty	1 ft. soil, sandy; 38 ft. sand and gravel.	Good	Level topography; Sand Prairie.
Plenty	1 ft. sandy soil; 1 ft. gravel; 30 ft. sand and gravel...	Good.	
Plenty	All in sand and gravel.....	Good	At Soenby; several wells near, all in coarse sand and gravel 10 to 20 ft.; overwash plain.

WELL RECORDS OF THE

Reference	Quarter	Sec.	Twp. & Range	Township	Depth	Height of Water
Page 54	NW	34	137, 58	Oakville	20	7
Page 54	SE.	28	137, 58	Oakville	50	....
A89, page 14	SW	33	136, 56	Moore	72	
A91, page 14	SW	....	136, 55	Liberty	50	25
A93, page 14	NW	30	136, 55	Liberty	60	....
A95, page 15	SE	12	136, 56	Moore	50	....
A97, page 15	SE	20	136, 55	Liberty	80	20
A99, page 15	NE	32	135, 55	Casey	42	....
B2, page 16	....	....	136, 54	Sheldon	17	....
B3, page 16	....	....	136, 54	Sheldon	18	....
B5, page 16	....	....	136, 54	Sheldon	30	4
B13, page 17	SE	2	136, 54	Sheldon	30	4
B15, page 18	NW	12	135, 55	Casey	28	4
B23, page 19	NW	4	136, 55	Liberty	65	....
B24, page 19	Center	4	136, 55	Liberty	54	....
B26, page 20	NE	7	136, 53	Liberty	12	....
B28, page 21	NE	12	136, 55	Moore	46	....
B31, page 22	NW	10	136, 56	Moore	40	....
B32, page 22	SW	13	136, 56	Moore	40	....
B34, page 23	NW	9	136, 56	Moore	60	30
B39, page 24	Center	6	136, 56	Moore	45	27
B40	SE.	1	136, 57	Preston	30	15
B58, page 27	NE	20	136, 56	Moore	75	....
B59, page 27	SW	16	136, 56	Moore	50	....
B66	SW	22	136, 56	Moore	70	18
B67, page 29	NE	26	136, 56	Moore	76	....
B68	NW	25	136, 56	Moore	32	2
B85, page 33	SE.	20	136, 55	Liberty	65	
B91	SE.	8	136, 55	Liberty	56	2
B93, page 34	SE	28	137, 55	Pontiac	41	....
B94	NE	28	137, 55	Pontiac	52	....
B95	NW	26	137, 55	Pontiac	80	....
B99, page 35	SW	32	137, 55	Pontiac	45	8
C6, page 35	NW	24	137, 55	Pontiac	90	....
C7	SE	14	137, 55	Raritan	38	20
	Lucca City	....	......	....	20 to 28	....
			137, 56	Raritan	20 to 50	....
C43, page 41	....	....	137, 57	Thordenskjold	125	....
E73, page 84	NW	11	138, 57	Norman	7	....
E97, page 87	SE.	35	139, 56	Springvale	35	

TOWER QUADRANGLE—Continued

Yield	Character of Rock	Character of Water	Remarks
Plenty	All coarse gravel and sand	Good	Near Soe nby; overwas plain.
Plenty	Soil, 2 ft.; clay and boulders, 30 ft.; coarse sand, 15 ft.	Good	
Plenty	Gravel bottom.		
Plenty	...	Hard.	
Plenty	...	Good.	
Plenty	Quicksand and gravel at bottom.		
Plenty.			
Plenty	Clay to sand at bottom	Good.	
Plenty			
...	Much quicksand; sandy clay	Good.	
Plenty	Gravel at bottom.		
Scant	Blue clay, sand and gravel		
Plenty	Brown clay		
Plenty.			
Plenty	Sand and gravel.	...	In coulee.
Plenty.	Gravel at bottom.		
...	Gravel and blue clay.		
Scant	Hard blue clay at bottom.		
Plenty.			
Plenty.	Sand and gravel at bottom		
...	15 ft. yellow clay; 15 ft. blue clay		
Scant	Blue clay and quicksand.		
Scant	...	...	Hard to get water.
...	Gravel at bottom.		
...	Hard, blue clay	...	Very difficult to get water.
Plenty.			
Scant.			
Plenty	...	...	Dug 25 ft.; drilled 16 ft.
Not abundant	Quicksand and gravel	Good	In Maple valley.
...	Blue clay at bottom.		
Plenty	Sand and gravel.	...	Dug.
Plenty	Clay and sand.		
Plenty	Clay and sand.		
Plenty	Gravel vein supplies water		
Plenty	Quicksand and gravel veins	Good.	
Plenty	...	...	Bored 2-inch hole.
Plenty	...	Alkaline.	

THE WATER SUPPLY OF THE ECKELSON QUADRANGLE.

By William H. Westergaard.

The Eckelson quadrangle includes the region lying between 98 degrees and 98 degrees 30 minutes west longitude and 47 degrees and 47 degrees 30 minutes north latitude. Its length is approximately thirty-four and one-half miles in the north and south direction, and its width twenty-four miles from east to west. Its northern boundary is approximately one and one-half miles north of the northern boundary of the tier of townships numbered 140, or about five miles north of the main line of the Northern Pacific railroad. The eastern boundary passes directly through Valley City, includes portions of the Sheyenne valley and passes Kathryn and Fort Ransom about three miles to the west. The southern boundary lies nine miles south of the Barnes and Ransom county lines, which is approximately nine and one-half miles south of LaMoure, and two and one-half miles south of Dickey. The western boundary crosses the main line of the Northern Pacific railroad one-half mile west of Spiritwood, and passes Dickey one and one-half miles to the west.

The area included in the Eckelson quadrangle comprises portions of four counties, viz., Barnes, Stutsman, LaMoure and Ransom. The southwestern portion of Barnes county constitutes at least two-thirds of the northwestern portion of the quadrangle. Stutsman county is represented by a strip twenty-four miles long and three miles wide along its eastern border, LaMoure county by a portion from its northeastern corner twenty-two and one-half miles long and nine miles wide, and Ransom county by a small strip from its northern and western corner nine miles long and one and one-half miles wide.

Water Resources.—The available water supply of any region may be classed as surface water supply and subterranean water supply. Under the head of surface water supply we may consider streams, lakes, sloughs, ponds and springs. Under the head of

subterranean water supply we may consider the water which is obtainable in wells by digging, boring or drilling.

Subterranean Water.—In general the wells of the Eckelson quadrangle obtain their water supply from three different horizons or water levels. With regard to these horizons we may group the wells into three quite distinct classes. The first consists of the wells in which a water supply is obtained without penetrating the bed rock or shale. These are the shallow wells dug in the drift material over or above the shale. The second class consists of those wells which penetrate the bed rock or shale. These are the deeper wells, which are usually bored to some water vein of sandy material in the shale. The third class consists of those wells known as artesian wells in which water is found under shale. These wells are drilled through the shale formations to a water bearing "sand rock" or sand stone.

Wells Which Do Not Penetrate the Shale.—The chief source of a permanent water supply aside from the deep tubular and artesian wells consists of wells dug to water which soaks through the surface material to reservoirs of porous substances like sand or gravel. These are the ordinary dug wells which penetrate the drift to depths varying from ten to 125 feet, the average depth being from twenty to forty feet.

The material in which these wells are dug consists of the "mantle" or top layer of material called "drift" which covers the bed rock or shale of this area to depths of from ten to 125 feet. This "drift" is a heterogeneous mixture consisting of what is commonly called clay mixed with sand, gravel, and bowlders. The sand and gravel may be quite evenly or uniformly mixed with the clay or it may be found in layers or veins varying from a few inches to several feet in thickness. It may even be found in pockets and often in streaks running through the clay. Usually the sand and gravel layers show a stratification of the finer material, the stratification tending to be horizontal though not necessarily so. These variations are due to the morainic origin of this drift material, it having been brought and left by the glaciers at the time known as the "Ice Age."

In spite of the fact that these wells show such a wide variation in depth, material passed through, and in the supply and value of the

water obtained, a few general statements may be made. Clay constitutes at least three-fourths and perhaps four-fifths of the material. Wells dug where the surface features are markedly morainic are usually dug through more gravel and sand near the surface. The clay is also more stony, *i. e.*, more mixed with sand, gravel and bowlders, and in general the chances are better for striking some water reservoir at a shallow depth. Wells dug in river benches are usually dug almost entirely in gravel and sand. The average well on the Eckelson quadrangle is dug from ten to forty feet in a whitish-yellow oxidized clay in which are interspersed a number of layers of sand and gravel commonly called water-veins. Beneath the yellow clay is found a harder, dark colored unoxidized clay called blue clay in which are also found a number of gravel and sand reservoirs called "water veins." This blue clay, sometimes very much mixed with sand and gravel, constitutes the material lying between the yellow clay and the "bed rock" or shale. From a study of numerous well records it would seem as though the sand and gravel water-veins were more numerous in the yellow clay than in the blue clay. Usually a water bearing stratum is struck between yellow and blue clay, the blue clay forming a harder and more impervious layer than the yellow. If a good supply of water is not secured after penetrating the yellow clay a better supply can usually be obtained by going deeper into the blue clay. The water-vein in this case is usually quicksand, though it may be sand or gravel. A stratum of quicksand usually has a hard layer over it called "hard pan," consisting of a mixture of clay, sand and course gravel. The water often rises with considerable force when this "hard pan" layer is pierced, especially where the water bearing stratum is of considerable extent and thickness.

The best kind of a well for general purposes is one dug in yellow clay to a water-vein of sand or gravel. The water in this kind of a well is seldom under very high pressure, and does not rise to any considerable extent above the water-vein. Under these conditions no large quantity of water will be allowed to stand in the well and become contaminated or dissolve large quantities of the soluble salts from the material constituting the wall of the well. Water in very deep wells is usually bad, because a water-vein under high pressure is struck, and a large amount of water is allowed to stand

in the wells and dissolve the alkalies and other soluble salts constituting such a large amount of the soluble material of the clay walls.

In the southwestern part of the Eckelson quadrangle is a region called "Sand Prairie" which constitutes the greater part of Bear Creek, southern Oakville, and northwestern Litchville townships, extending from there into the Tower sheet on the east. This region is very level land, and appears to have been a lake bed in glacial time. The wells here are very shallow, being dug in stratified sand to a depth of from seven to twenty feet. The water is very good, but very slightly hard. The average depth of the sand is probably about thirty or forty feet.

A small, sluggish intermittent stream called Bear creek winds its way from the Sand Prairie region southward to the James river. Good water in sufficient quantity is very hard to obtain in the region immediately west of Bear creek in eastern Litchville and southwestern Bear Creek townships. The reason for this scanty water supply is that the shale is found a few feet beneath the surface, and in this shale very few water bearing strata are found, and where found; usually yield water unsuited to general uses.

In the vicinity of the city of Litchville, in southwestern Lincoln and northwestern Prairie townships, good water is hard to obtain. Wells are frequently dug to depths of sixty to 125 feet, but the supply of water is scanty and usually of poor quality, being very hard and alkaline. No strong water bearing stratum is ordinarily found here in penetrating the drift to the shale or "slatestone" bed rock.

In the region near to the James valley on either side, in Roscoe, southern Saratoga and southwestern Sheridan townships, good water of sufficient quantity is usually obtained by digging the well in some coulee or ravine having drainage into the James river. Usually a stratum of gravel or sand may be struck at quite shallow depths near the bottom of these coulees or "water-ways." In the higher land many wells have been dug to shale, but quite often very little water and of an inferior quality is obtained.

The conditions immediately west of the Sheyenne valley are somewhat similar to those adjoining the James valley. Water is hard to obtain on the high areas. Shale is struck before any water bearing stratum of much consequence is reached.

Another region where good water is obtained with difficulty is found in the eastern portion of township 40, range 61, in the vicinity of Eckelson, and west of Eckelson lake. A plentiful supply of water can usually be obtained in deep wells, but it is usually very hard and alkaline.

In southern Prairie and southwestern Litchville there are considerable areas where water is obtained almost invariably in sufficient quantity in quicksand. Throughout the quadrangle there are numerous other localities of similar extent where water is obtained in quicksand, southern Spring Creek and northern Scandia being examples.

The region immediately surounding Sanborn, in central Potter and Marion, in northern Sheridan towships, are examples of localities where good water is ordinarily obtained at depths of thirty to thirty-five feet.

In the markedly morainic regions the wells vary most widely in character, but here wells of good water in abundant supply are nearly always obtainable if good judgment is exercised in selecting a locality.

There are a few wells in this quadrangle, usually bored wells, which have been sunk deep enough to penetrate the shale. In some of these strong water bearing strata have been struck, but usually the chances are that no satisfactory water supply can be obtained in this way, unless the wells are bored to a sufficient depth to penetrate the artesian or Dakota sandstone. Water obtained in shale usually has a salty, disagreeable taste, being heavily laden with soluble salts.

A number of artesian wells have been drilled in the territory between Litchville and Ft. Ransom, at depths varying from 950 to 1,150 feet. Some of these exert a pressure as high as seventy pounds per square inch at the surface of the ground, and furnish an abundance of water valuable for general purposes. It is safe to say that these artesian wells may be secured on any portion of the Eckelson quadrangle, although the pressure may be rather weak in the higher areas near the northern part of the quadrangle.

Springs furnish a constant supply of good water from outcrops along the banks, and in ravines and coulees along the Sheyenne and

James valleys. These springs usually occur at some point where the valley has been cut into shale, the shale forming an impervious layer on which the water collects in sufficiently large quantities to escape as a spring. This is especially obvious in the Sheyenne valley.

ECKLESON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 14	Valley, NW 21.....	26	23	Sand and gravel all way...............
1, 4	NW. 21.............	30	27	Sand and gravel all the way..........
1, 29	Litchville, section 4.	15	5	Surface loam and yellow clay... ....
1, 29	Section 4...........	28	25	Surface loam and yellow clay.........
1, 29	NW. 10.............	20	17	Sandy yellow clay....................
1, 29	Section 10,...... ..	40	30	....
1, 29	Section 10..	25	19	....
1, 30	Section 2......	20	15	Yellow clay, quicksand, blue clay ....
1, 30	Oakville, NW. 30....	9	8	Gravel and sand to blue clay.........
1, 30	Spring Creek, SE. 24	13	4	11 ft. yellow clay.......... ....
1, 31	NE. 24..............	25	13	Yellow clay...........................
1, 31	Section 22...........	8	5	Yellow clay ....
1, 31	Section 22	29	25	Yellow clay...........................
1, 31	Section 26...........	22	12	Yellow clay........... ....
1, 32	Section 22..........	36	18	10 ft. yellow; 13 ft. blue; sandy blue clay
1, 32	Prairie, NW. 14.....	82	72	20 ft. yellow; 20 ft. blue; 5 ft. sand; 37 ft, blue clay.........................
1, 32	NW. 14......	42	37	20 ft. yellow; 20 ft. blue sand ....
1, 32	NE. 14.........	32	22	20 yellow; 18 ft. blue gravel........ ..
1, 33	NE. 14..	42	30	20 ft. yellow; 20 ft. blue gravel- .....
1, 33	Prairie, SW. 14.....	32	28	25 ft. yellow; 6 ft. dark yellow material in chunks with vertical cracks.....
1, 33	SE. 14..............	30	18	Yellow clay, blue sand......... .....
1, 33	S. 22	40	38	30 ft. yellow; 5 ft. blue; 13 quicksand..
1, 34	SE. 10..............	150	No water	35 ft. yellow; 60 ft. blue; 8 ft. sand shale; deposit to shales 103 ft........ ....
1, 34	S. 23...............	30	24	Yellow and blue clay............. ....
1, 34	S. 23.......	16	4	Blue clay to quicksand........... ...
1, 35	S. 22............. ..	45	43	30 ft. yellow clay; 6 ft. gray sand......
1, 35	S. 26.............. ..	37	35	Yellow clay and sand (quicksand). ..
1, 35	S. 26......	40	37	Yellow clay to sand.................
1, 35	(Griswold) S. 27. ...	28	25	Yellow sandy clay....................
1, 36	S. 26...............	42	36	32 ft. yellow; 6 ft. blue hardpan........
1, 36	S. 27	36	34	26 ft. yellow; 7 ft. blue; 3 inches hardpan
1, 36	NE. 34..............	42	40	38 ft. yellow clay; 4 ft. quicksand......
1, 36	Gladstone, NW. 2...	38	36	32 ft. yellow clay; 6 ft. sand...........
1, 36	SW. 2......	30	27	20 ft. yellow; 10 ft. blue-gray sand.....
1, 37	SE. 2	28	22	18 ft. yellow; 6 ft. blue.............. ...
1, 37	Gladstone, NW. 12..	40	3[illegible]	18 ft. yellow (hard); 2 ft. dry sand; 3 ft. quicksand; 15 ft. blue clay........
1, 38	Prairie, SE. 36	38	32	....
1, 38	SW. 24	45	35	Yellow clay, quicksand, blue clay,....
1, 38	SW. 26.......	15	12	Blue clay................... ....
1, 34	SW. 24	100	No water	Shale at 80 ft... ....
1, 38	NW. 12...	45	40	7 ft. yellow; 18 ft. blue gravel veins; blue clay....... ....
1, 39	SW. 12	30	26	32 ft. yellow; 7 ft. blue-yellow sand....
1, 39	S. 12.	32	28	....
1, 40	T. 139, R. 58, NW¼ 6	34	24	Yellow clay and veins of sand.........
1, 41	NE. 6	140	50	Some shale at 30 ft.....................
1, 42	SW. 6	21	15	Sand and gravel......................
1, 43	Greene, NE. 12......	35	32	Yellow and blue clay.......... ....
1, 43	SW. 1 . .	28	20	... .
1, 46	Greene, SE. 10......	22	8	Yellow clay and gravel................
1, 47	NE. 10......... .	29	26	Gravelly yellow clay, hardpan ......
1, 48	NW. 11....	14	10	7 ft. black loam; 10 inches white clay; hard, yellow clay..................

SHEET

Bottom	Character of Water	Supply	Character of Surface	Remarks
Sand & gravel	Nearly soft..	Good	Valley slope.	NW. corner of Valley City.
Sand & gravel	Nearly soft..	Fair	Valley slope.	NW. corner of Valley City.
Sand..........	Nearly soft..	Good.		
....	Hard, good..	Good	Level.	
Quicksand ...	Hard.........	Poor.		
....	Hard.........	Good	....	Dug 60 ft. in blue clay.
....	Soft..........	Good.		
Blue clay.....	Hard.........	Poor.		
Blue clay.....	Soft..........	Good	NW edge of S. Prairie..	
Quicksand ...	Hard.,.......	Good	Foot of Sand Prairie hill.	Wells alike one half mile apart.
Quicksand ...	Hard.........	Good	In Maple hills......	
Gravel.......	Soft, good...	Good	Ravine	Boulders many.
Gravel........	Soft, good.			
Sand,blue clay	....	....	....	Blue clay at 22 feet.
Sandy blue clay.........	Nearly soft..	....	....	Clay more sandy with depth.
Blue clay.....	Salty	....	....	May be shale in bottom.
Sand	Alkaline.....	....	....	All close together.
Gravel........	Hard.........	....	....	
Gravel........	....	....	....	
Coarse sand..	Hard.........	....	....	Material in bottom shale like
Quicksand over blue clay........	Hard-........	....	....	Quicksand rather coarser than usual and mixed with gray soil.
Blue clay.....	....	....	....	Claimed to be northern edge of quic sand belt
Shale.........	Salty	....	....	Shal ternated with 10 inches hard material and 7 or 8 ft. is softer and lighter.
Quicksand ...	Soft..........	....	....	½ mile apart.
Quicksand ...	Soft..........	....	....	In ravine (east).
Quicksand ...	Hard	....	....	Quicksand under coarser sand.
Quicksand ...	Hard.........	....	....	Believe quicksand would be found in 40 ft. well if dug deeper; wells close together.
Sand	Hard.........	....	....	
Quicksand (white).....	Hard.			
Quicksand ...	Hard.........	....	....	Griswold P. O.
Quicksand ...	Hard.			
Quicksand ...	Hard.			
Coarse brown sand........	Hard.			
Quicksand ...	Soft, good.			
Quicksand ...	Hard.			
Gravel and blue clay....	....	....	....	Considerable water in the quicksand.
Quicksand ...	Hard, good.			
Blue clay.....	Hard	....	....	Quicksand vein very thin.
Quicksand.				
Shale.				
Blue clay.....	Hard; alkali.			
Sand (yellow gravel	Hard.			
Blue clay.				
Clay....	Very hard...	....	....	Blue clay at 60 ft. here.
Shale.........	Salty	....	....	Tastes like artesian water.
....	Hard.			
....	Hard.			
....	Slightly hard			
Gravel........	Hard	Poor.....	Side hill.....	Side of Maple Ridge.
Sand..........	Hard	Good	Maple hill...	
Yellow cla ..	Limelike, bitter.........	Poor.....	Gravel valley	

ECKLESON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 49	SW. 2	32	29	Gravel to sand
1, 50	NE. 11	25	21	Loam and yellow clay, 5 ft.; gravel, 5 ft.; blue clay, 15 ft
1, 51	NE. 2	20	17	Yellow clay to gravel and sand
1, 53	139, 58, section 8	21	11	15 ft. yellow clay, sand and gravel
1, 53	Section 8	42	38	15 ft. yellow clay, sand, blue clay, hardpan
1, 55	139, 58, section 7	50	16	10 ft. yellow; 40 ft. blue
1, 56	Section 18	30	54	25 ft. yellow and blue clay shale
1, 57	Section 29	60	....	Yellow and blue clay
1, 58	Section 32	200	....	....
1, 58	Oakville, section 7	22	14	Yellow clay and gravel
1, 59	Section 7	18	8	Yellow clay and small stones
1, 59	Spring Creek, Sec. 12	70	....	10 ft. yellow clay; 60 ft. blue clay
1, 60	Section 28	30	24	15 ft. yellow clay; 15 ft. blue clay
1, 60	Spring Creek, Sec. 20	40	Little wat'r	Yellow and blue clay
1, 62	Oakville, SW. 29	15-13.5	14-11.3	Gravel all way
1, 63	Oakville, Sec. 20	33-27	31-25	Yellow clay; gravel
1, 63	Oakville, Sec. 28	30	27	Yellow, stony clay
1, 64	Oakville, center of E. ½ of section 28	60	58	Yellow and blue clay 20 ft.; gray sand 40 ft
1, 65	Oakville, section 32	19	17	Gravel and sand
1, 65	Oakville, section 34	24	22	Gravel and sand
1, 66	Bear Creek, Sec. 6	14	12	Gravel and sand
1, 67	Bear Creek, Sec. 8	8	6	Gravel and sand
1, 67	Bear Creek, NW. section 17	7	5	3 ft. soil and clay; 4 ft. sand
1, 67	Bear Creek, Sec. 18	8	6	3 ft. soil and clay; 5 ft. sand
1, 68	Ft Ransom, Sec. 18	24	20	3 ft. soil and clay; 14 ft. gravel; 7 ft blue clay
1, 68	NE. section 18	12	10	2 ft. soil (upper); 4 ft. sand blue clay
1, 70	Black loam, Sec. 13	30	26	Yellow and some blue clay
1, 70	Ft. Ransom, Sec. 18	15	10	Sand and gravel
1, 71	Ft. Ransom, Sec. 7	32	16	Yellow bluish sand and blue clay
1, 71	Ft. Ransom, Sec. 8	11	7	2½ ft. loam; 7½ ft. yellow clay; 6 in shale
1, 72	Ft. Ransom, Sec. 5	12	10½	2 ft. loam; yellow, sandy clay
1, 72	Bear Creek, Sec. 32	12	10	Gravelly sand
1, 73	Black loam, Sec. 1	46	25	19 ft. yellow clay; 21 ft. dry sand; 6 ft chalk-like clay
1, 73	Ft. Ransom, Sec. 6	30	20	Dug in clay and shale
1, 74	Bear Creek, Sec. 30	36	No water	Dug in hard blue clay
1, 74	Latchville, section 24	15	9	Red sand, quicksand
1, 75	Bear Creek, Sec. 19	158	No water	4 ft. sand; 2 ft. clay; 32 ft. blue shale; 42 ft. white shale (chalkstone); 78 ft. soft blue shale
1, 75	Latchville, section 24	39	24	3 ft yellow clay; 36 ft. blue clay; quicksand
1, 76	Latchville, section 12	54	14	12 ft. yellow clay; 22 ft. blue clay; yellow, blue sand
1, 76	Latchville, section 2	73	[illegible]	10 ft. yellow clay; 60 ft. blue clay; gravel
1, 77	Oakville, section [illegible]	7	5	Gravel and sand
1, 79	[illegible], section 25	48	46	10 ft. yellow clay; 38 ft. blue; boulders and gravel
1, 79	[illegible], section 25	80	70	20 ft. yellow; 30 ft. blue gravel and sand; 30 ft. blue clay
1, 8[illegible]	[illegible], section 25	127	120	17 ft. yellow clay, 25 ft. blue clay; sand vein; 60 ft. blue clay; shale

ET—Continued.

ottom	Character of Water	Supply	Character of Surface	Remarks
....	Slightly hard	Good	On Maple hill	Valley bottom marshy; sand prairie at foot of hills.
ksand ...	Hard.	Poor.....	On hill.......	Numerous springs in valley below.
clay.....	Hard........	Good	Side hill.	
clay.....	Alkaline,h'rd			
....	Hard,alk'line	Good	....	Slaty hardpan at 40 ft.
ksand ...	Hard,alk'line	Fair	Valley bottom.	
....	Bitter, salty, alkaline....	....	Low and level	Shale in sight here at depth of probably 25 ft.
....	Very bitter, alkaline...	....	Low........	May be shale in this well.
....	No water....			
el & sand	Hard........	Fair	Slope.	
el........	Soft..........	Good.		
y clay...	Hard,alk'line	Poor.		
ksand ...	Slightly hard	Fair	High ground	
: clay, ie gravel	Hard,alk'line	Poor.....	Low prairie.	
el.	Nearly soft..	Good	High prairie.	
: sand...	Hard........	....	Foot of hill..	Wells quarter mile apart.
el, sand.	Soft,..........	Good	Foot of small ridge.	
....	Soft..........	Strong, good...	On hill north of sand prairie.....	Northern edge of sand prairie.
....	Nearly soft..	Good	Very level, low........	Sand prairie region.
....	Nearly soft..	Good	Level, low...	Sand prairie.
, gravel..	Nearly soft..	Good	Level, low...	Sand prairie.
, gravel..	Nearly soft..	Good	Level, low...	Sand prairie.
....	Nearly soft..	Good	Level, low...	Sand prairie.
....	Nearly soft..	Good	Level, low...	Sand prairie.
y gravel.	Hard........	Poor.....	Slightly rolling prairie.	
....	Good, muddy	Fair	Level prairie	Clay, gravelly.
, gravel..	Nearly soft..	Fair	Level prairie	
clay.....	Poor, alk'line	....	....	Clay, stony.
,uicks'nd	Nearly soft..	Good	Level........	Ft. Ransom hill toward east.
ksand ...	Nearly soft..	Good	Level.	
ksand ...	Good, nearly soft........	Good	Low level.	
:like clay	Good, nearly soft........	Fair	Low level ...	Probably shale at 40 feet.
....	Salty	Poor.....	Low level ...	Shale in bottom.
....	....	....	....	May be shale in bottom.
ksand ...	Fairly soft...	Comes in fast....	Rolling prairie.	
clay.....	....	....	Nearly level prairie.	
ksand ...	Hard........	Comes in fast....	....	Water in other wells salty.
w, blue d..	....	....	On hill.	
el vein..	Good, hard.			
el........	Good	Comes in fast....	Level........	Sand prairie.
:s, gravel	Hard,alk'line	Poor.....	Nearly level.	Litchville City.
el, sand.	Hard,alk'line	Poor.....	Level........	Litchville City.
:.........	Hard, alk'ne	Poor.....	Level........	Litchville City.

ECKELSON

Book and Page	Location	Depth	Depth to Water	Character of Rock
1, 81	Scandia, S. 20	32	28	20 feet loam and clay (yellow), 6 feet gravel, 3 feet blue clay
1, 82	Scandia, S. 8	18	13	Yellow clay and gravel
1, 82	Scandia, S. 5	61	36	27 ft. yellow clay, 34 ft. blue clay
1, 83	Green, S. 28	28	25	2 ft. black loam, 3 ft. yellow. 23 ft. yellow clay
1, 84	Green, S. 22	20	18	2 ft. soil, 18 ft. yellow clay
1, 85	Sp. Creek, S. 2	12	6	Yellow clay
1, 86	Sp. Creek, S. 20	45	15	6 ft. yellow, 35 ft. blue clay with sand streak, hard pan
1, 88	Sp. Creek, S. 32	65	....	Yellow and blue clay to shale (at 60 ft.)
1, 88	Litchville, S. 7	20	18	Yellow clay, gravel and sand
1, 89	Litchville, S. 8	92	42	20 ft. yellow clay, 40 ft. blue clay, shale and blue clay
1, 90	Litchville, S. 18	90	....	15 ft. yellow clay, 45 ft. blue clay, shale [clay(?)]
1, 92	Litchville, S. 20	27	21	8 ft. yellow clay, 19 ft. blue clay, quicksand in bottom
1, 93	Litchville, SW. 30	85	....	6 ft. yellow, 25 ft blue, gravel and sand, blue clay
1, 93	Litchville, SW. 30	120	115	30 ft. yellow, 40 ft. blue, 50 ft. blue shale
1, 94	Litchville, NE. 28	45	25	15 ft. sand, 30 ft. gravel and clay, hard pan
1, 95	Litchville, SE. 27	19	9	12 ft. coarse gravel, 7 ft. gravelly blue clay
1, 97	Black loam, SE. 4	42	32	15 ft. yellow clay, 27 ft. blue clay
1, 99	Prairie, SW. 2	60	....	20 ft. yellow clay, 3 ft. dry sand, 36 ft. blue clay
1, 100	Lincoln, NW. 32	35	33	Yellow and blue clay
2, 1	Gladstone, NW. 4	22	18	Yellow and blue clay
2, 1	Black loam, SW. 18	30	20	15 ft. yellow clay, 15 ft. blue clay
2, 2	Black loam, SW. 8	49	44	Yellow and blue clay, (water at 30 ft. in sand)
2, 3	Black loam, SW. 2	24	20	23 ft. yellow clay, 1 ft. quicksand
2, 4	Black loam, NE. 3	20	....	Shale at 20 feet
2, 5	Prairie, SW. 10	57	42	20 ft yellow clay, 12 ft hard blue, 25 ft. sandy blue
2, 6	Prairie, NW. 28	45	41	Sandy clay for 40 ft, hard pan, sand
2, 7	Prairie, SW. 28	46	44	35 ft. yellow clay, 16 ft. blue clay, quicksand
2, 8	Prairie, NW. 34	30	15	Layers of yellow clay, gravel, sand, black gumbo, etc

SHEET—Continued

Bottom	Character of Water	Supply	Character of Surface	Remarks
Quicksand	Hard	Very g'd	....	Boulders numerous.
Sand & gravel	Soft	Good	Edge of glacial slough.	
Sandy blue clay	Hard	Fair		
Gravel & sand	Nearly soft	Very g'd	Edge of low flat	Surroundings morainic. Water level in flat same.
Quicksand	Very hard	Good	Nearly level.	
Sand	Nearly soft	Very g'd	Near edge of slough.	
Gravel under hard pan	Salty	Poor.		
Blue shale				
Blue clay	Hard	Comes in fast	Near edge of creek.	
Shale	Soft, fairly good	Does not come in fast		
Shale	....	....	....	Claim shale was not struck until 90 feet was reached.
Quicksand	Hard.			
Shale	....	....	....	Considerable water in gravel and sand at 30 feet.
Shale	Hard, salty	Poor	On high mor. hill.	
Clay	Hard,alk'line	Fair		
Blue shale	Hard,alk'line	Fair	....	Shale here between 45-60 feet.
Quicksand	Hard.			
Gravelly blue clay	Very little water	....	....	Shale here at 100 feet.
Gravel	Hard, good	Comes in fast	High rolling prairie.	
Quicksand	Soft,	Comes in fast	On hill	Surrounding morainic
Stone& gravel	Hard	Comes in fast	....	Quicksand in well close by at 38 feet.
Blue clay	Hard.			
Blue clay	....	V'ry poor	High	Shale in other well at 91 feet.
Shale	....	Poor	Near slough.	Have dug as deep as 57 feet and found little water.
Coarse grey blue sand	Hard	Comes in fast	High, rolling	
Quicksand	Hard	Comes in fast	High flat-topped hill.	
Quicksand	Hard	V'ry poor	....	Quicksand 12 ft. Blue clay under sand.
Quicksand	Hard	Comes in fast		

INDEX

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Agricultural College Survey of North Dakota

TO THE

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ADMINISTRATIVE REPORT AND ACCOMPANYING PAPERS FOR THE YEARS 1905-6

DANIEL E. WILLARD
Director

BISMARCK:
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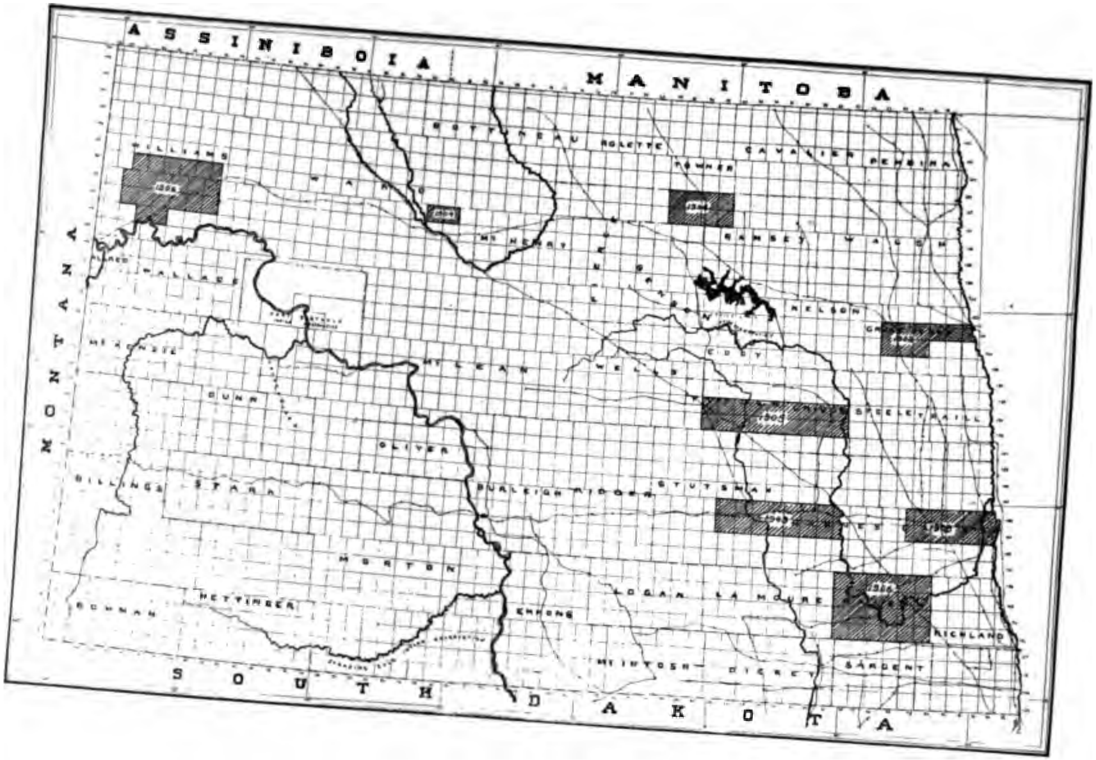
PLATE I



PROGRESS MAP SHOWING SOIL SURVEYS.

A

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CONTENTS

ILLUSTRATIONS

LETTER OF TRANSMITTAL

Hon. E. Y. Sarles, Governor of North Dakota:

SIR: I have the honor to transmit herewith the Third Biennial Report of the Agricultural College Survey of North Dakota, with accompanying papers, for the years 1905 and 1906.

In addition to the administrative report, in which are described the different lines of investigation that have been pursued, together with recommendations for the future, several papers are presented which set forth quite fully the character of the work that has been done, and by their nature explain their value.

In a state in which the agricultural resources are destined by nature to be the chiefest economic resources, there would seem to be urgent need for the scientific study of those facts and conditions that form the foundation of the prosperity and wealth of the commonwealth.

There is therefore no need to explain why the efforts of the survey have been directed along the lines of the investigation of those problems that are directly or indirectly related to agriculture. The papers that accompany this report it is thought deal with problems that are of the most vital interest and importance to the agricultural development of the state. It is hoped, therefore, that as wide publicity as possible will be given to these papers, and that the legislative assembly of 1907 may be requested to bring this report to the attention of as large a number of practical farmers in the state as possible.

Yours very respectfully,

DANIEL E. WILLARD,

Director.

Agricultural College, North Dakota, November 15, 1906.

THE THIRD BIENNIAL REPORT

OF THE

AGRICULTURAL COLLEGE SURVEY

OF NORTH DAKOTA

BY DANIEL E. WILLARD, DIRECTOR.

History and Purpose.—The Agricultural College Survey was organized by act of the legislative assembly of 1901. The survey has therefore had legal and actual existence for a period of six years. During this time the development of the state of North Dakota has advanced at a pace which would have been deemed impossible a few years ago.

During such a time of rapid growth and development along all lines it would seem especially fitting that the state should lend aid toward the investigation of her natural resources, and should seek to avoid the possibility of future loss and discouragement to her citizens by assisting so far as practicable in the determination of the best methods of developing and utilizing the native resources.

The work represented by ths survey, viz., the investigation of the types, character and qualities of the soil, the study of the extent and character of the underground water supply, and the investigation of those geologic facts and conditions which are at the foundation of agriculture and allied industries, and the publication and distribution to the public of the results of these investigations, is therefore deemed to be among the most important things that could be done at this time, looking toward the permanent upbuilding and prosperous development of this new state.

During the biennial period the lines of work which were in progress during the preceding period, and which were described in the report of the director for the years 1903-4, have been continued. The work of the present biennial period is represented by the following lines, some idea of the character of which may be gathered

from the accompanying papers: (a) Soil surveys, conducted in co-operation with the bureau of soils of the department of agriculture; (b). topographic surveys, by the U. S. geological survey; (c) investigations of underground (artesian) waters, in co-operation with the U. S. geological survey, section of hydrology; (d) areal geology, folios of the Geological Atlas of the United States, in co-operation with the U. S. geological survey, division of hydrography; (e) field work in preparation of preliminary geologic map of North Dakota; (f) biological survey of North Dakota.

While it is not possible to report as much work done in any of these lines as it would be pleasant to relate, still it is with pleasure that I am able to report as much accomplished as has been done. During the past two years 2,178 square miles of soil surveys have been made, and soil maps have been prepared showing the character of the soil in detail for every section of land represented.

A topographic map of the Bismarck quadrangle has been prepared representing an area approximately twenty-five miles in extent east and west and thirty-five miles north and south, and embracing one-fourth of a square degree of the earth's surface.

An investigation of the underground waters of the eastern portion of the state, with especial reference to the extent of the Dakota artesian basin, has been in progress during the period since my last biennial report, and a report upon this important subject is now in progress of preparation, and will be published for general distribution by the U. S. Geological Survey.

Areal geology investigations, by which is contemplated the detailed geologic mapping of definite areas, showing all the surface features from which the various soil types are developed, and the geologic character upon which depend the natural resources of a region, have been carried on upon two quadrangles, embracing an area of about 1,650 square miles, the territory studied embracing a tract extending about fifty miles westward from Valley City, in Barnes and Stutsman counties, and having a width from north to south of about thirty-five miles.

The field studies looking toward the revision and completion of the preliminary geologic map of the state have been carried on as far as the funds available have made possible.

The biological survey of the state has been systematically organized. This survey contemplates the collection and classification of the native forage and other useful and injurious plants of the state,

and the study of the soil and moisture conditions under which they grow, with a view to determining from these studies of the native plants in their natural conditions what cultivated plants can be most successfully and profitably grown.

The effort is being made to fulfill the purpose described in the law by virtue of which the survey has existence, viz., to "complete a topographic, geologic and economic survey of the state, and to prepare a map of the same," etc.

The plan that has been followed has been to distribute the work of the several surveys over districts somewhat removed from each other, so that in the shortest possible time a study should have been made of all the principal soil types of the state, and as much geologic data as possible collected, having an immediate bearing upon the economic development of the state.

The Progress of the Survey of the State.—In a state comprising as large an area as North Dakota the proportionate amount as compared with the whole area that can be brought under the detailed investigation contemplated by the Agricultural College Survey in any single year is not large. Encouragement should be taken from the fact that progress has been made. Neither is the value and importance of the work done to be measured by the extent in square miles of the areas surveyed. It is hoped that with the progress of the state and the increase in knowledge and appreciation of her natural resources a larger amount of money may be applied to this work on the part of the state, and thus the amount of work that can be done each year be greatly increased.

Thus far progress in the survey of the state has been made about as follows: Topographic surveys, with published maps showing the elevation of all parts of the land surface, also showing all public highways, railroads, towns, farm houses, streams and lakes, in short, all information necessary in a base map for the further detailed study of the areas, have been made of about one-eighth of the entire state.

Soil surveys have been made aggregating about one-twentieth of the total area of the state.

Geological investigations, represented by the completed work of folios of the Geologic Atlas of the United States, have been completed upon about one-half of the quadrangles that have been topographically surveyed and mapped, or about one-sixteenth of the total area of the state.

The first topographic survey was made in the state in 1894. If no greater progress is made in the future than during the twelve years from 1894 to 1896 it will require about ninety-six years, or nearly one century, to complete the topographic survey of the state!

During the six years since the organization of the Agricultural College Survey five quadrangles have been surveyed, and folios of the Geologic Atlas of the United State completed or are in preparation. At this rate of progress to complete the area represented by the state of North Dakota in the Geologic Atlas of the United States, that is, to complete the geologic and economic map of the state of North Dakota contemplated by the law organizing this survey, would require also about ninety-six years, or nearly a century.

During the three biennial periods that this survey has been in existence 3,834 square miles of land have been critically studied and mapped by soil surveying parties. At this rate a soil map covering the entire state would be completed in about 120 years!

These figures at first thought seem discouraging. In reality discouragement is idle. Those nations and states, like individuals, have succeeded best and prospered most which have kept diligently at work seeking by the aid of scientific investigation to elucidate the best methods of utilizing their natural resources. The matter is not one for discouragement, but the question is rather how much can be done each year and every year toward the more perfect solution of the agricultural and economic problems of our state. When it is borne in mind that North Dakota embraces an empire as large as all the New England states combined, with the state of Delaware and half of New Jersey added, we may then better understand the figures which at first looked so appalling, and may turn and congratulate ourselves that we are so fortunate as to be the possessors of so vast an empire, and one possessed of so great natural resources to be investigated.

Co-operation in Soil Survey Work.—It is desired to call attention especially to the progress that has been made during the past two years in the study and mapping of the soils of the state.

Through the very generous treatment accorded us by Professor Milton Whitney, chief of the bureau of soils, department of agriculture, considerable has been accomplished toward the completion of a soil map of the state. A brief description of the work accomplished during the past two years follows:

During the summer of 1905 Mr. A. E. Kocher was sent from Washington to have charge of a soil survey of an area extending across the southern portions of Griggs and Foster counties, embracing twenty townships, 460,800 acres. Mr. Kocher was furnished an assistant from Washington, Mr. L. A. Hurst. All the expenses of these two men were borne by the federal bureau. In order to accomplish the survey of as large an area as possible an arrangement was entered into whereby two men, Mr. John T. Weaver and Mr. Rex E. Willard, were sent from the agricultural college to assist Messrs. Kocher and Hurst, all the expenses for livery service for the double party being generously borne by the federal department, the only expense accruing to the state being that for the salaries and maintenance of the two assistants sent from the college. Messrs. Kocher and Hurst reached Cooperstown on May 1st, and remained upon this field until September 15th. Messrs. Weaver and Willard were on the field from June 15th to August 15th.

A detailed report of this survey will be found among the accompanying papers of this report.

During the winter preceding the present season of 1906 requests were received for soil surveys in Williams and Ransom counties. Both these projects seemed worthy of consideration and would be to the advantage of the state. However, the funds supplied by the state for survey work had been overdrawn in 1905, and it seemed impossible to furnish the necessary assistants to enable the bureau of soils at Washington to undertake the survey of these two areas. The problem of the finances was, however, solved very happily by the people of these two counties offering to contribute the funds necessary to secure the survey. Accordingly a plan was arranged whereby two men should be sent from Washington, each capable of assuming charge of a survey, an assistant to each of these men to be furnished by the Agricultural College Survey. All livery service for both parties was to be paid by the bureau at Washington.

Accordingly on May 1st, 1906, Mr. Thomas D. Rice reached Williston, and Mr. Chas. W. Ely assumed charge at Lisbon.

The desire was expressed by Professor Whitney, chief of the bureau of soils, that as thoroughly trained men as possible be sent as assistants. Accordingly Messrs. Weaver and Rex Willard, who had each been with soil surveying parties at least two seasons previously, were asked to accept appointments as assistants on these surveys in Williams and Ransom counties.

A thoroughly and detailed survey of an area embracing sixteen and one-half townships was surveyed in Williams county, under the direction of Mr. Rice, and the whole of Ransom county was surveyed by Mr. Ely's party. Detailed reports with full descriptions of the soils and a colored map of each of the areas will be published by the bureau of soils, and these reports and maps will be reproduced in the next biennial report of the Agricultural College Survey. A preliminary report on these surveys appears among the accompanying papers of this report, that upon the Williams county area having been very kindly prepared by Mr. Rex E. Willard, and that on the Ransom county area by Mr. John T. Weaver.

For these surveys, it should be added, all the expenses for the subsistence for the assistants, and nearly the whole of their salaries, were contributed by the people of Williams and Ransom counties respectively.

Geologic and Economic Map of the State.—Accompanying the first biennial report of this survey there appeared "A Preliminary Geologic and Economic Map of North Dakota," prepared by the late Professor C. M. Hall, who organized the Agricultural College Survey and was its first director. This map embodied the results of all the investigations that had been made—chiefly under federal direction and at federal expense—up to the time of its publication, and included a preliminary classification of the soils, showed the distribution of the more important geologic features that have a bearing on the agricultural value of lands, the extent of the Dakota artesian basin, all the known workable outcrops of lignite coal, and the average annual rainfall for all the stations in the state where such records are systematically kept.

This map has been very widely distributed in response to a very general and earnest demand. It is thought it has been a very valuable means of showing the resources of the state to contemplating homeseekers and investors. The demand for the map has been so unprecedentedly large that an edition of 10,000 copies, which was first brought out, was soon exhausted, and a second impression of 10,000 copies was authorized by His Excellency, Governor Frank White. The last edition has been nearly exhausted, sent largely to persons who requested copies individually.

This map was issued in January, 1903. Since that time considerable progress has been made toward a more nearly complete map of the state. Much valuable data has been gathered, and important

investigations have been made which should be expressed on this map. It is therefore planned to complete the work of revising this map in the near future so as to make it express as completely as possible all the investigations that have been made looking toward the development of the state.

Soil Map of the State.—With the development of agricultural industries in the state and the increase in the acreage of farm lands, and also with the increase in the values of farm lands thereby rendering the need for improved methods of farming more imperative, the demand has increased for a systematic study of the soils of the state. It will be seen from the progress map at the beginning of this volume that systematic soil surveys have been made in nearly all parts of the state. A brief description of these surveys, and some of the reasons that led to the selection of these areas, follows: (a) Two surveys have been made in the Red River valley, extending from the Red River of the North westward across all the formations deposited in the waters of ancient Lake Agassiz. (b) A tract extending from Valley City to the highland of the Missouri plateau west of Jamestown, this tract being selected since by it are crossed practically all the principal soil types of east-central North Dakota, and particularly the region represented by the Sheyenne and James River valleys. (c) An area covering the southern portion of Towner county, including within its limits some of the most fertile land in North Dakota, and representing in the various soil types there observed the greater part of the north-eastern portion of North Dakota. (d) A small area in Ward county, the territory covered by the survey being a representative tract in the noted Mouse River county, the area being so located that it includes the soil types formed on the bottom of the ancient Lake Souris, and also the soils of the rolling prairie outside the immediate basin of the ancient lake. (e) A survey of townships 145 and 146 extending across Griggs and Foster counties. This soil area includes some very fertile farming land and also some types the nature of which need to be carefully studied in order to be profitably farmed. The types here observed include those of the areas of the upper Sheyenne and James rivers, and of the plain extending westward to the base of the great Missouri plateau, a portion of the geographic landmark known as Hawk's Nest, located principally in the southeastern corner of Wells county, being included in the area surveyed. (f) A tract embracing sixteen

and one-half townships in southern Williams county, known as the Williston area. The Williston area represents the newer portion of the state, and one where the demand for a study of the soils is great as an aid to the immigrant settler who is trying to establish a home upon these hitherto uncultivated prairies. It was felt that here especially there was need for a soil survey, since these new lands are in a region where the methods of farming employed in Iowa and Illinois will not likely be successful without some adaptation to meet the different conditions. Under these conditions a soil survey means much toward the substantial and successful development of the region. The types of soil observed here moreover are representative of a vast region in the northwestern portion of the state beyond the immediate area surveyed. (g) The Ransom county area. The soils of Ransom county represent an interesting group of soil types, and include some that have not been met with elsewhere in the state. The survey of Ransom county makes it possible to construct a fairly accurate map of all the principal soil types in the southeastern portion of the state.

From these several surveys in somewhat widely separated portions of the state it is possible to construct a general soil map of the whole state such as will show approximately the character of the soil in every section of the state. The soil surveys have been distributed over the state with the idea in mind that a soil map of the state should be able to be made without the necessity of waiting for detailed surveys of every township. Such a map when completed should be of inestimable value to the farmers of North Dakota.

Soil studies of this character have been made in various parts of the United States, and much valuable assistance has been rendered thereby in the development of the agricultural resources of the various states. Industries that had never been thought of have been suggested by the study of the soils and the comparison of these with those of other regions, and later these suggestions have been adopted and profited by to the great advantage of the commonwealth.

It is true that the enterprising farmer will by experiment find new methods of farming, and will learn by experiment that other crops can be successfully and profitably grown than those that have been long known to the neighborhood. But experimenting is nearly always expensive, and it is not every farmer who is able to make

the necessary investment of time and capital. Particularly is it the case that new settlers in a region, who oftentimes have come from a locality so far distant that agricultural conditions are very different, are with difficulty able to make the necessary experiments to determine what methods of cultivation and what crops will be most successful and profitable. The burden of such experimenting may be in considerable measure relieved by a systematic study of the soils in relation to their adaptabilities to methods of farming and kinds of crops.

In view of these considerations, it is with justifiable satisfaction that the announcement is made that a soil map of the state of North Dakota in colors showing the soil types in all parts of the state is in preparation, and it is hoped will be able to be offered to the public in the near future. Such a map entails a large amount of painstaking labor, but it is thought that when completed it will be worth manifold more than what it cost.

Division of Chemical Investigations.—The division of chemical analysis of soils and waters of the Agricultural College Survey has made only very modest advancement owing to the limited funds available for this work. Mr. John T. Weaver has prepared a valuable paper relating to the chemistry of the soils of the Cooperstown-Carrington area, which will be found among the accompanying papers of this report.

Biological Survey of the State.—The biological survey of the state, by which is contemplated more immediately the collection and determination of all the native forage plants of the state, and a study of their associations with the natural soils, with a view to determining the adaptabilities of the various soils to cultivated crops, has been this season carried forward in a very efficient manner by Dr. W. B. Bell, of the department of biology of the Agricultural College, who spent two months on the Williston soil area in company with the soil surveying party. A preliminary report on this work appears among the accompanying papers of this report. The Agricultural College bore half the expense of the biological work this season, as otherwise it would have been impossible for the work to have been carried on, owing to the deficiency in the funds for carrying on the work of the survey. Work of so much importance and value to the state ought not to be allowed to be handicapped for the lack of funds to carry the work along.

The Geological Museum.—The accumulation of geological material, as provided and required by section 4, chapter 8, session laws

of 1901, viz: soils, rock specimens, fossils, sands and gravels, clays and bricks, plants illustrative of the nature of soils, etc., etc., has continued till the question of space for adequately exhibiting the material has ceased to be considered, and the bare place for storing the materials as they are brought in from the field has become the one thing thought of.

Plans have been under consideration for some time looking toward the making of a soil museum, the plan of which contemplates that while it should be a museum for exhibition, yet it should also be educational in its character, showing by the plan of its arrangement and construction the relation between the soil of the field and the plants that grow upon that soil, both those native to the soil and those that can be successfully grown by cultivation. A large amount of material has been collected, but as suggested, no adequate opportunity is now afforded for its display.

It may be added that a small beginning has been made toward displaying the soils of the state in glass jars. Several hundred scientifically classified soils from every area in the state where a soil survey has been made are now packed in drawers in the laboratory, stowed in boxes, and piled on the floors. These samples have been collected at considerable expense, but are now serving no useful purpose for lack of opportunity to display them.

Needs of the Survey.—The funds that are annually appropriated by the state for the conduct of the investigations that are being undertaken by the survey, and which are described in this report, form but a meagre part of the cost of the work. It is only through the generous co-operation of the federal departments at Washington that it has been possible to carry on the work.

All the expenses connected with the investigations relating to the underground water supply; those relating to the execution of the folios of the United States Geologic Atlas, including the costs of publication; and the entire cost of making topographic surveys and the publication of the topographic sheets, have been borne entirely by the federal government, yet the state and the Agricultural College receives the benefit and credit of the work.

Likewise in the conduct of the soil surveys which have been made in our state in co-operation with the Bureau of Soils, more than three dollars out of every four expended for carrying on the work in the field have been paid by the federal government, and

in addition all the cost of publication has been borne by the federal department, while the state has shared freely in the credit for the work.

One of the primary necessities to future work along the lines represented by the Agricultural College Survey is the completion of topographic surveys, and the preparation of the accompanying topographic sheets or maps. As has been before stated, these sheets form the base maps on which all further geologic work of whatever character—mapping of soils, underground water investigations, the Geologic Atlas—is done.

The importance of this kind of work has been fully appreciated by the federal government and by many of the state governments. The topographic division is therefore considered to be one of the most important of the United States Geological Survey.

It is the plan of the United States Geological Survey to co-operate with the several states in the preparation of topographic maps in all the states to the end that a topographic map of the whole area of the United States shall ultimately be made.

Wherever co-operation is offered by a state the federal government purposes to expend at least an amount equal to that contributed by the state for the work. Thus every dollar appropriated by the state counts for two dollars in the prosecution of the work.

As has been elsewhere stated, at the rate that topographic surveys have been made in North Dakota since 1894, when the first sheet, the Fargo quadrangle, was surveyed, it will require about *one century* to complete a topographic survey of the state. Hitherto no financial co-operation has been offered the federal government by the state, and what work has been done, therefore, has been done solely at the expense of the federal government.

The amount appropriated by the state annually for the maintenance of the Agricultural Survey is $1,000. As the Survey was organized to co-operate with the federal surveys, the amount made available by the state would naturally determine the amount of co-operation into which the federal surveys would enter, and the amount also which the state desired. However, the federal authorities have taken good will at its full value, and have expended a much larger amount than the state appropriated in the hope that more active co-operation on the part of the state would be provided in the future. The aggregate expended by the federal surveys in co-operation with the Agricultural College Survey in the divisions

of soil, areal geology, underground waters, and topography is approximately $10,000 for the years 1905-6, aside from the cost of publication of reports.

It can hardly be hoped that the federal authorities will continue to expend funds so generously in our state unless some active appreciation of the generosity manifested be shown by reasonably adequate provision of funds by the state.

As has been stated, the topographic survey forms the basis for all further detailed surveys. The cost of making a topographic map averages about $3,000. The policy of the government is to expend in each state an amount equal to that provided by the state itself. In order to have the topographic survey progress with rapidity and in accord with the general progress of the work in other lines, one sheet at least should be prepared each year. Thus the state in order to meet the generosity of the federal government should provide $1,500 per year for this work.

Similarly, the work of the soil survey has been heretofore done almost entirely by the federal department, but in the hope that the state would realize the benefit and value of the work and provide an annual sum sufficient to meet that offered by the federal government. For this work the federal government has expended during the past two years about $5,000.

In addition to the lines of co-operation above mentioned, the Agricultural College Survey has, in conformity with the purpose expressed in the law organizing the survey, undertaken to complete an economic and geologic map of the state. As a part of this work the survey has undertaken the preparation of a map showing the different characters of lands, the soils and waters, also the native grasses and forage plants, in the western portion of the state—a portion of the state, as has been stated before, that has never been accurately mapped—looking toward a more complete geologic and economic map of the state. For this work $1,000 per year is needed.

I would also most respectfully urge the necessity of provision of sufficient funds to maintain the chemical and biological divisions of the survey, and also to provide for permanently preserving specimens of soils, rocks, minerals and other material, such as is being collected each year, but for the preservation of which no adequate provision has been made.

The investigations which are contemplated in the division of chemistry include both field studies and laboratory analyses. Five

hundred dollars per year for the biennial period will be needed to carry to satisfactory completion the field and laboratory investigations which it is hoped to undertake, $300 being the estimated necessary cost of the field work, and $200 that for laboratory materials, and the services of competent assistants.

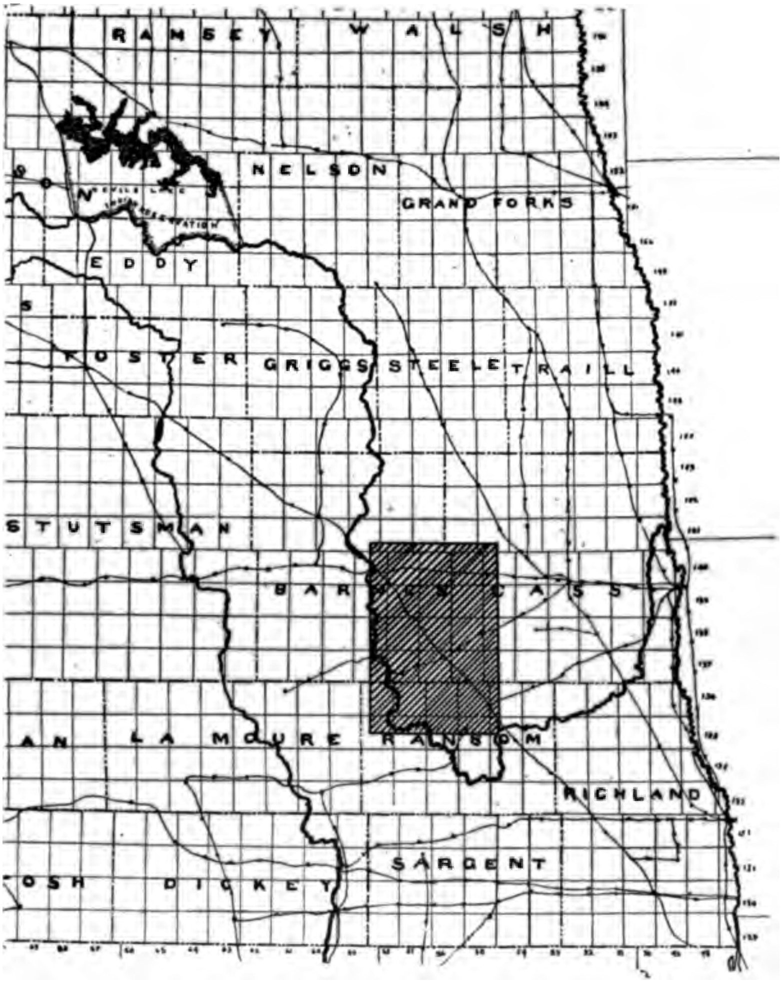
For the biological survey and the preservation of material collected in the work, $500 per year ought to be expended in order to yield the best results.

In the interest of the fullest conservation of the results of the survey, I would recommend that suitable cases for the preservation and storage of the valuable material which is each year collected by the different field parties be made. One hundred dollars per year would make it possible to preserve each year material the value of which is almost beyond expression in figures.

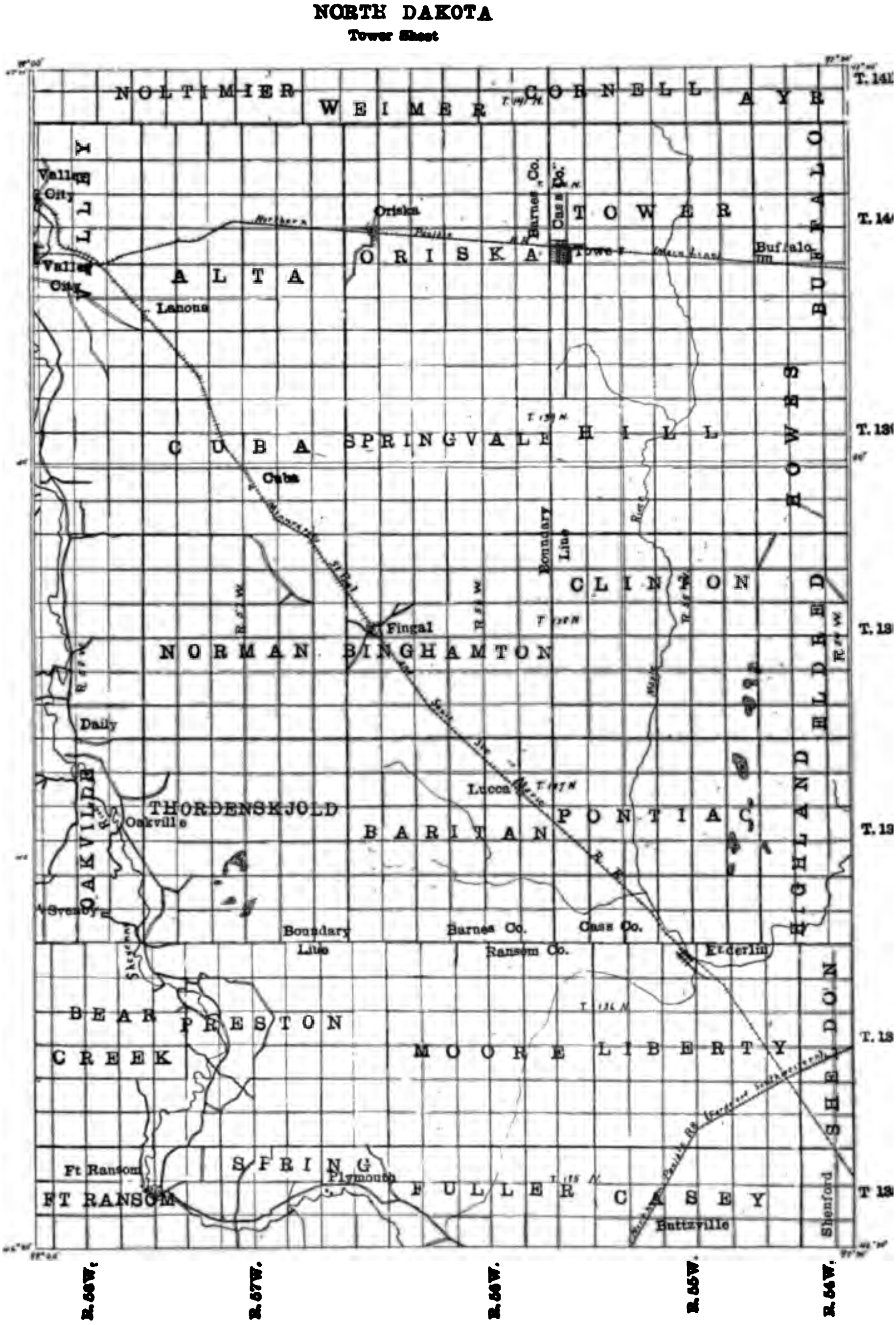
Summarizing the above figures, I desire to recommend the appropriation of the following amounts, to be used in the discretion of the director for the following purposes:

Object For Which Used	Annually
For topographic survey	$ 1,500
For soil surveys	1,500
For surveys in western portion of state....	1,000
For division of chemical investigations....	500
For biological survey	500
For preservation of material	100
For director's expenses and incidentals....	400
Total for all purposes	$ 5,500

ACCOMPANYING PAPERS



(a) INDEX MAP SHOWING POSITION OF THE TOWER QUADRANGLE.



(b) THE TOWER QUADRANGLE.

(Referred to in the text as Fig. O.)

DESCRIPTION OF THE TOWER QUADRANGLE.

By Daniel E. Willard.

GEOGRAPHY.

Location.—The Tower quadrangle (see figure O) is bounded by the meridians 97 degrees 30 minutes and 98 degrees west longitude, and by parallels 46 degrees 30 minutes and 47 degrees north latitude, being about twenty four and three-fourths miles in width and about thirty-four and one-half miles in length, and comprises about 826 square miles. It includes portions of Cass, Barnes and Ransom counties, North Dakota. The eastern boundary of the quadrangle coincides nearly with the western limits of the floor of the ancient Lake Agassiz, commonly known as the Red River Valley. The Herman beach, the highest shore line of Lake Agassiz, crosses the eastern boundary of the quadrangle near its middle point. The eastern and southern boundary lines follow approximately the course of the deep glacial Sheyenne valley.

Geographic Relations.—Eastern North Dakota is embraced in the Great Plains region, and is crossed by the indefinite divide that separates the waters of the Gulf slope from those of the Hudson Bay slope. It is comprised within the area of glaciation of North America, and its surface features show the characteristics of a drift-covered region. The country is generally level, but presents broad slopes or escarpments, caused by preglacial erosion, the latter rising often 300 to 400 feet above the plains to the eastward. The slopes are generally mantled with drift, which occurs in long, low ridges formed at the edge of the retreating ice-sheet during the time of deglaciation of the continent. Further diversity of topography has been produced by the excavation of the valleys of the Missouri, the James and the Sheyenne rivers. Between the morainal ridges occur gently rolling plains of till, or nearly level plains due to the filling of glacial lake basins. The Red River Valley is a notable example of lake-bed topography.

Topography.—The topography of the Tower quadrangle is that of a gently undulating plain, in places nearly flat. The eastern

part of the quadrangle has a general elevation above sea level of about 1,100 feet, though the small portion of the bed of glacial Lake Agassiz contained within the area is crossed by the contour of 1,060 feet, and the channel of the Sheyenne river, in the extreme southeast corner of the area, rises slightly above the 1,000-foot contour. The highest part of the area is a broad swell called the Alta ridge, in the western portion of the quadrangle, the highest points on this ridge being three small areas in range 57 west, which rise above the 1,500-foot contour. Beyond the crest of the Alta ridge to the westward the surface declines 100 feet or so, in places directly to the crest of the bluffs forming the east side of the Sheyenne river valley, and elsewhere to the nearly flat Lanona plain, several miles in width, beyond which is the sharply cut valley of the Sheyenne river. The eastern slope of the ridge declines rather rapidly 200 feet or more to the gently undulating plain of the Maple river basin.

The northeast central portion of the quadrangle is a nearly level plain, relieved, however, by low, symmetrical hills. The northeast corner of the area, and most of the eastern half south of the level plain referred to, is marked by morainic ridges and elongated hills, which have an unmistakable north-northwest and south-southeast trend. The south central portion of the area is rolling in character, the hills having the rough and irregular outlines of marginal deposits from the ice sheet, small lakes and undrained sloughs being of frequent occurrence. The southwestern part of the area has the rough surface of a hilly plain deeply trenched by short valley, the alignment of the hills being generally north and south. Northward across the west side of the quadrangle the Alta ridge is traversed by lines of hills which are less rugged in character, and are set with many small lakes and other undrained depressions.

The broad and deep valley of the Sheyenne river extends along the western boundary of the area southward throughout nearly its whole extent, swinging eastward in a broadly sinuous course near the southwest corner. It continues near the southern boundary nearly to its center, leaving the area in section 18, Fuller township. After flowing a distance of five or six miles a little south of its limits, the stream turns north and east and again enters the quadrange at the extreme southeast corner, in section 17, Shenford township Here the bed of the stream represents the lowest point of the quadrangle.

Drainage.—The greater part of the Tower quadrangle has no surface drainage whatever, the waters from rains and melting snows being absorbed or evaporated. Shallow lakes without outlets and undrained sloughs are frequent. Several ancient channels occur within the area, but none, with the exception of the Sheyenne valley, is occupied by a permanent stream.

The Sheyenne river is the principal stream of the area. Though its drainage area embraces nearly 2,000 square miles, the volume of water discharged into the Red River of the North is estimated to be less than that flowing through Valley City, nearly 150 miles up the stream. The loss is due to evaporation and absorption as the stream meanders sluggishly over the broad, flat bottom of the ancient valley which it traverses. The crest of the Alta ridge, which lies four or five miles to the eastward and parallel with the Sheyenne valley, is about 300 feet above the bottom of the valley, yet there are no modern stream channels to carry away the water from the region between this crest and the shoulders of the bluffs which immediately overhang the river.

In times of heavy rains and melting snows a system of ancient channels is occupied by the Maple river and its tributaries, but ordinarily, though this constitutes the drainage system for an area of more than 1,000 square miles, the run-off is insufficient to maintain a permanent stream. The issuance of springs along its banks alone prevents it from entirely drying up during the summer seasons.

Although the plain of the lake bed of glacial Lake Agassiz lies immediately to the eastward of the area, 400 feet lower than the crest of the Alta ridge and 200 feet lower than the general level of the eastern half of the quadrangle, still there are no eastward flowing streams in obedience to this fall of 400 feet in the distance of fifteen miles.

The history of the development of the ancient valleys of the area is given in a subsequent connection.

The great continental watershed between the Hudson Bay basin and the Gulf slope crosses the Tower quadrangle in the extreme southwest corner, and divides its drainage into two very unequal parts. The divide as represented on this area is made up of two strongly contrasted topographic features, viz., the sharp morainic crest of Bears Den Hillock, in section 10, Bear Creek township, and a portion of the almost level tract of Sand Prairie four miles northwest of this. The streams to the northeast of this watershed belong

to the system of the Red River of the North, while the rivulets parted away to the southwest flow into Bears Den Hillock creek, a member of the great Mississippi-Missouri river system.

The Sheyenne river rises in McLean county, very near the geometrical center of the state of North Dakota: thence it flows in a generally easterly course through a distance of 100 miles, passing south of Devils Lake fifteen to twenty miles: turning southward in southern Nelson county it flows south by east until it reaches Fort Ransom township, in the southwestern part of the Tower quadrangle. Between Fort Ransom and section 17, Shenford township, where it re-enters the quadrangle after leaving it in Fuller township, the river makes the most significant bend throughout its course. After rounding what is locally known as the Big Bend below Lisbon, the river follows a northeast course across the bed of glacial Lake Agassiz to its debouchure as a tributary of the Red River of the North at a point twelve miles north of Fargo. The great bend by which the stream in its lower course flows almost in the opposite direction from that in its upper course is a marked feature of all the tributaries of the Red River of the North.

The approximate length of the Sheyenne river is 325 miles: the area actually drained is less than 2,000 square miles; the mean width of the area drained is therefore about six miles. This mean width is maintained approximately uniform throughout its course, the tributary valleys at all points of the stream being very short, from a few rods to two or three miles in length. The entire basin of the Sheyenne river is estimated to be approximately 12,000 square miles.

The fall of the Sheyenne from source to mouth is three and one-half feet per mile. A considerable part of this fall is given the stream by its descent from the escarpment of the Plateau du Missouri. From the point of its entrance upon its glacial delta across the lake bed of glacial Lake Agassiz to its debouchure the fall is a little less than two feet per mile. In this floor of unconsolidated lacustrine sediments the river has intrenched itself in a narrow, sharply incised valley. Where the river crosses the Tower quadrangle, through a distance of about forty miles, the flood-plain falls about one and one-half feet per mile, a slight rapids being developed where the valley crosses the moraine near Fort Ransom.

The Sheyenne valley, where it enters the Tower quadrangle, in township 140 north, range 58 west, about three miles above Valley

City, has a width from bluff to bluff of about one mile. The flat bottom is here about 180 feet below the general prairie level. At Valley City, however, the valley becomes suddenly wider, so that the width of the plain that has been covered by the waters of the river is fully five miles. This high terrace will be described elsewhere as the Lanona plain. One and one-half miles south of Valley City the valley is about one and three-fourths miles wide between the bluffs. The prairie plain adjacent is nearly 200 feet above the broad, level flood-plain. Thirty miles below Valley City, in section 36, Bear Creek township, a point in the valley known as the Jaws is only a little more than one-half mile in width, and the flood-plain lies about 150 feet below the general level of the prairie. About ten miles below the Jaws, where the river leaves the quadrangle, the valley is about one mile wide, and has a depth below the prairie level of about 100 feet. At the extreme southeast corner of the quadrangle the valley is about one-quarter mile in width and has a depth of about fifty feet.

A DESCRIPTION OF GEOLOGIC FORMATIONS IN EASTERN NORTH DAKOTA.

By Daniel E. Willard.

General Relations.—Excepting the slopes of the Sheyenne river the Tower quadrangle (see figure O) is covered by a considerable deposit of glacial drift. Beneath the drift, wherever penetrated by deep borings, some hundreds of feet of soft blue-black shale have been encountered. The Sheyenne river, in eroding its valley in the western part of the quadrangle has cut down through the glacial drift 10 to 150 feet into this shale, so that, where not obscured by the sliding down of glacial debris from above, exposures of the shale are afforded.

It is often very difficult to determine at just what depth the shale is first encountered in drilling wells, owing to the similarity between the glacial clay and the shale from which it was very largely derived. Boulders occur in the drift, but it is not often that an accurate report can be obtained from the drillers as to the depth at which the last boulders were encountered. The issuance of springs from the slopes of the river valley frequently serve to indicate approximately the horizon of contact betwenen the shale and the overlying drift.

CRETACEOUS DEPOSITS.

Pierre and Colorado Shales.—So far as there has been opportunity for determination from the meager exposures in the slopes of the river valley and from the records of several deep wells the deposits beneath the glacial drift consist of blue-black shale with intercalated layers of sand. In the lower part of the shales lime concretions and thin layers of hard rock, called by the drillers "iron ore," also occur. No fossils have been found within this area, so that the age of the shale can only be inferred from its relations to formations in neighboring regions whose age has been determined, and to the underlying sandstone, which is referred to the Dakota.

The Pierre shales outcrop in extensive cliffs 100 miles to the northward.

Upham reports the finding of *Inoceramus sagensis,* Owen, fragments of other lamellibranchs, and *Baculites ovatus,* Say, on the western slope of a hill, partly bared of drift and consisting of Pierre shale, near the west line of section 33, townshtip 139 north, range 58 west, eight miles south of Valley City and about one and one-half miles west of the Sheyenne river, at an elevation above sea level of 1,350 feet, and about 175 feet above the river.[1]

It is probable that all of the shales exposed at the surface on this quadrange (see figure O) belong to the Pierre, but the lower beds overlying the Dakota doubtless include equivalents of both the Benton and the Niobrara, which may be conveniently designated Colorado shales, the two not being clearly distinguishable.

The thicknesses of shales on the Tower quadrangle with descriptions of same, are shown in the followings logs:

Sonik well, section 28, Howes township (T. 139 N., R. 54 W.):

	FEET
Soil and yellow clay, with stones	130
Blue clay, with sand layers	319
Total depth	449

Talcott farm section 13, Tower township (T. 140 N., R. 55 W.):

	FEET
Soil and clay	150
Hardpan	10
Blue-black clay-shale	446
Total depth	606

Card well, section 34, Hill township (T. 139 N., R. 55 W.):

	FEET
Clay with boulders	200
(Two flows separated by an interval of about sixteen feet, reported at this horizon.)	
Shale	360
Total depth	560

Tower City well, section 19, Tower township (T. 140 N., R. 55 W.):

	FEET
Soil and clay	164
Blue clay-shale	502
Quicksand	5
Total depth	671

[1] Upham, Warren, The Glacial Lake Agassiz: Mon. xxv, U.S.G.S., 1896, p 92.

Silsand well, section 19, Bear Creek township (T. 136 N., R. 58 W.):

	FEET
Soil, sand and clay	8
Dark shale	40
Light gray shale	320
Hard, dark shale	100
Sandstone	2
Hard, dark shale	300
Iron pyrites	1
Softer dark shale	100
Shale, with layers of sand rock from six to ten inches thick	50
Total depth	950

Nome City well section 13, Thordenskjold township (T. 137 N., R. 57 W.):

	FEET
Soil, sand and clay	40
Yellow clay	20
Gravelly and stony blue clay	48
Gravel and stones, hard	22
Tough blue clay	140
Iron ore (varying from two inches to two feet in different wells)	1
Blue clay	85
Iron ore	3
Hard layer	2
Blue clay, with layers of fine sand	300
Hard clay, like hardpan	10
Sand and clay (first flow, called "drip and flow")	42
Hard layer, containing iron	0½
Clay	28
Hard layer	0½
Clay with fine sand (second flow)	45
Clay and fine sand in alternating layers, with thin layers of iron ore	35
Clay and sand (more sand below), final flow	23
Total depth	888*

Depths of other wells on the quadrangle which penetrate the Dakota formation, are as follows:

	DEPTH
Lewis well, section 29, Howes township (T. 139 N., R. 51 W.)	536
Gromish well, section 21, Howes township	425
Smith farm, section 11, Raritan township (T. 137 N., R. 56 W.)	749
Major Buttz well, section 17, Casey township (T. 135 N., R. 55 W.)	730
A. O. Rufsvold well, section 7, Spring township (T. 135 N., R. 57 W.)	885
(Depth to principal flow, 860 feet.)	

*The log of the Nome well is stated by the driller to represent the records of a number of wells in this vicinity.

	DEPTH
Ernest Billings well, section 14, Spring township.......... (Depth to principal flow, 900 feet.)	945
J. Peterman well, section 28, Spring township............	900
Ole Rufsvold well, section 1, Fort Ransom township (T. 135 N., R. 58 W.)...............................	885
Well on Bear's Den Hillock, section 2, Fort Ransom township	1,070

Dakota Sandstone.—At depths varying from 450 feet in the eastern part of the quadrangle to 875 feet at Valley City, and 1,070 feet in section 2, Fort Ransom township, in the western part of the area, sandstone is encountered beneath the Pierre and Colorado shales. This is the source of the artesian waters within this area, and it is thought to belong to the Dakota formation.

The uniform salty character of the water from the artesian wells indicates the presence of sodium chloride in the sandstone.

Twenty-five miles west of this quadrangle, in the James river valley, sandstone regarded as belonging to the Dakota formation, is encountered at depths from 1,220 feet in range 62 west, to 1,470 feet in range 64 west.

Upon the western half of the Casselton quadrangle, which adjoins the Tower quadrangle on the east, borings penetrate the sandstone at depths of 300 to 400 feet.

These considerations together with the depths at which the sandstone is reached on the present area, show the westward dip of the Cretaceous formations.

THE QUATERNARY (DRIFT) FORMATIONS OF THE TOWER QUADRANGLE.

By Daniel E. Willard and H. V. Hibbard.

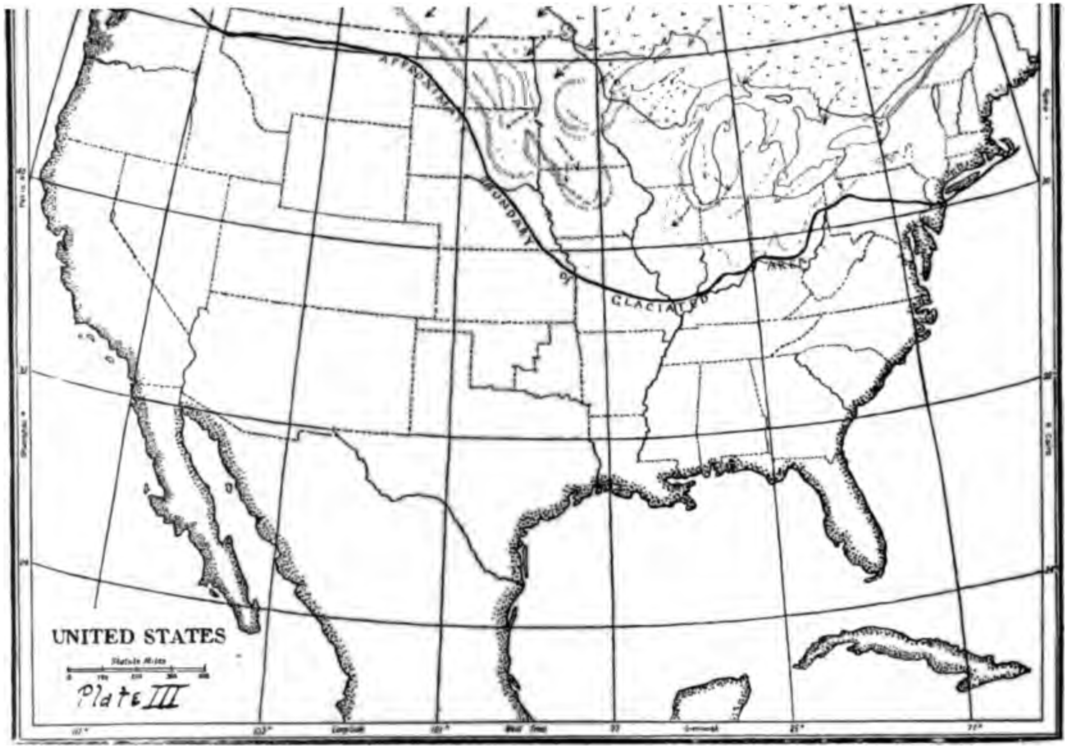
(By permission of the United States Geological Survey.)

General Character and Relations of the Drift.—The surface formations of the Tower quadrangle, except the slopes of the Sheyenne valley already referred to, are deposits made directly from the melting ice sheet or secondarily from the flood waters resulting from the melting ice. These deposits of unconsolidated material are grouped together under the general name of drift. While stratified deposits of sand, gravel and clay are of frequent occurrence, much of the drift is unassorted. The unassorted material consists generally of a matrix of clay in which are imbedded rock fragments of various sizes, shapes and lithological characters.

This clay is very similar in character to the blue clay resulting from the disintegration of the underlying shale, and indeed it appears that it was from this shale that the clay of the drift was very largely derived.

While the arrangement of the constituents of the drift is in large part heterogeneous, yet from the frequent occurrence of stratified materials in the deposit, especially in certain parts of the area, it is evident that considerable water must have taken part in the original deposition or in the arrangement of the deposits

The depth of the drift deposits over the area varies from a thin remnant of boulders to a deposit of 100 feet or more. The drift presents a minimum thickness on the upper flat plain of the west bluff of the Sheyenne valley from Valley City to Oakville, where it is represented by little else than scattered boulders resting upon or imbedded in the deeply weathered Cretaceous shale. A maximum thickness occurs on the Alta ridge, where well borings have reached shale at a depth of about 120 feet. The Sheyenne valley has been eroded deeply into the shale, and although the shale has been largely concealed by the talus of drift that has fallen down



MAP SHOWING THE EXTENT OF GLACIATION IN THE UNITED STATES.

Also the position of the principal Terminal **Moraines; the direction** of movement of the ice and the region of Archaean rocks from which came **the granitic and other boulders** commonly called "hard heads." (Referred to on p. 30 as figure b, and on p. 11 **as figure 1.)**

the valley sides, yet the sections of the drift thus revealed show its thickness here to be from fifteen to twenty feet.

The stony material of the drift ranges in size from coarse gravel to boulders two or three feet in diameter. Large boulders such as the last named are not generally abundant. Exceptions to this are the Alta ridge and the slopes of the Sheyenne valley, where these are in close proximity to morainic deposits. In the latter situation boulders from six inches to three feet in diameter literally form a pavement over considerable areas. Boulders gathered in heaps from the tilled fields on the Alta ridge show sizes averaging one foot in diameter.

The till beds are relatively free from stony materials, as shown by exposures in valleys and sections of the drift in railroad cuts and wells. Out of 200 well records ten only were reported as containing any considerable amount of stony material.

Granitic, trappean and quarzitic material make up the major portion of the stony material of boulder size. It is estimated that perhaps 10 per cent of the boulders is limestone. Not infrequently shale boulders and cobbles are found in the terraces and drift deposits. On the whole the foreign material constitutes a very small fraction of the glacier deposits. While small fragments of crystalline rocks may be seen upon minute inspection of the sand and clay beds, almost the entire body of the till is of local origin.

No impressions of the nature of grooves or striæ have probably been retained in the fragile Cretaceous shales which formed the floor beneath the moving ice—at least none were discovered. Subangular pebbles and small boulders with polished facets bearing the well known groovings and scratches of glacially striated stones occur in the body of the glacial deposits of this area, although not as abundantly as in corresponding situations in Illinois or Wisconsin.

The arrangement and direction of the terminal moraines indicate a west-southwest movement of the ice sheet. (See figure 1.) The region of Archaean rocks about 400 miles to the northeast seems to have been the home of the foreign material that has found lodgment in the drift of the quadrangle.

Lenticular pseudostratified masses of porous travertin-like limestone in which are included drift pebbles and cobbles, the whole presenting the structure of an ordinary conglomerate rock with a limestone matrix, were found in several places imbedded in the

drift closely associated with terminal moraines. One instance is in Madigan's coulee, section 4, Spring township, on the side of the valley near to and above a ledge of outcropping shale. Another is on the north bluff of the Sheyenne river, section 12, Fort Ransom township, in a gravelly mass of drift near its contact with the shale, exposed by a road cut leading into the Sheyenne valley. The most notable occurrence of this formation, however, is in the Glens of Kathryn, section 23, Oakville township, where an area of several hundred square rods, broken by deep gorges and hills and supporting a dense growth of small timber, is made up of large blocks and irregular masses of this limestone, scattered confusedly over the surface.

The Glens of Kathryn are situated on the sides of a tributary valley of the Sheyenne river, where the principal gorge has been eroded through the drift and 100 feet into the shales beneath. High morainic hills lying on the upper slopes of the valley to the south and west form a gathering area for water, which issues in the form of springs along the contact of shale and drift, and from crevices in the shale of the glens. The mineral charged waters of these springs may have deposited the travertin around and entrapped the coarser constituents of a talus of drift lying at the foot of the bluff, thus forming the conglomeric masses of a calcareous matrix and drift pebbles. That these rock bodies were not transported by the ice but were formed in situ is attested by their sharply angular outlines, and by numerous exposed and delicately crystalline surfaces.

A great mass of evidence has accumulated indicating that the glaciation of North America was not confined to a single stage of growth and decadence of the glaciers, but the vast sheets of ice were developed which spread widely over the surface of the land, and that after they had occupied the region for a period they were melted away in part, or perhaps wholly, to be later succeeded by renewed advances of the ice front. The glaciers of these successive invasions did not reach the same limits, and it is quite probable that the regions freed from ice during the warmer intervals were equally variable in extent. During the stages when the land was freed from ice new soils developed, vegetation grew, and erosion sculptured the surface of the drift previously deposited.

Evidence of more than one stage of growth and decadence of the continental glacier have been found on this area, but the history

of the stages of glaciation and deglaciation cannot at this time be fully written, owing to the fact that the earlier glacier deposits are so thoroughly commingled with the later drift, or so completely buried by it, that only an incomplete distinction can be made.

Evidence of deglaciation and the formation of soil and the accumulation of vegetable matter and the subsequent advance of the ice and burial of the surface materials accumulated during the time of deglaciation is afforded by the reports of peaty, mucky and lignitic matter encountered in digging or boring for water at depths of twenty to forty feet below the present surface. Evidence also of a period of erosion, which was in turn followed by a period of destruction of the landscape features developed, is afforded by certain topographic features which are best explained by reference to an earlier invasion of the ice sheet. Several examples of series of small lakes or lakelike depressions which occupy a single general long depression, but which are individually separated by low hills or hummocks of drift material occur on this area. One of the most notable is the Alice chain of lakes, in the eastern part of the area where the general line of depression can be traced through a distance of eight miles, nine lakes, besides nearly as many lake-like depressions, occurring in this distance.

These depressions vary in dimensions from twenty to forty rods in diameter to a half mile in width and one and one-half miles in length. The sides are steep, composed mainly of till, and are frequently bordered with cobbles and boulders. The bottoms are flat and lie at a depth of about twenty feet below the surrounding plains. Some of the depressions join, some are separated by low bars of gravel and sand, and others by ridges of till. Hills and ridges from ten to twenty-five feet in altitude, having gentle slopes and presenting the characteristics of kames, are found in close proximity to the sides of the lakes. Hills composed mostly of till and having the steep slopes of morainic deposits also occur. The alignment of the hills and ridges is generally parallel with that of the depressions, and the hills and ridges are never found to occur between the depressions.

Another example of what appears to be a blocked drainage channel extends northward from section 9, Spring township, through Preston, Thordenskjold and Norman townships, (Tps. 135, 136, 137, 137 N., R. 58 W.), a distance of fifteen miles. The southern five miles of this ancient water course, which is locally

known as Madigan's coulee, is a steep-sided ravine or gorge having a depth at its mouth of more than 100 feet, the sides being outcropping shales with overlying talus of the same material. Very little drift exists along the bottom or sides of this gorge. Ten miles to the northward from the head of this gorge the depression continues, though there is no continuous modern water-course. In sections 14, 11 and 2, Preston township, the depression contains several lake-like basins with intervening hills of morainal type. Thence it continues northward through sections 30 and 31, Raritan township, and 25 and 36, Thordenskjold township, thence being interrupted by a rolling hilly topography to sections 23 and 14, Thordenskjold township, thence soon extending three miles northward in a broad lake-like depression, beyond which it may be traced four or five miles, in Norman and Binghampton townships, as a flat till-plain interrupted by rolling hills.

The most obvious explanations of such chain-like series of basins, nearly all of which have their major axes in the general direction of the main depression, would seem to be that a valley, representing a period of erosion, had been blocked or partially filled by drift deposits during a subsequent period of glaciation and destruction of landscape features.

DEPOSITS OF THE WISCONSIN STAGE OF GLACIATION.

Ground Moraine.—The deposits formed and overridden during the advance of the Pleistocene glaciers compose the ground moraine. When the final melting took place, such drift as was lodged well up in the body of the ice or upon its surface was let down upon the subglacial deposits. Generally such additions of englacial and superglacial drift are not very clearly distinguishable from the drift deposited beneath the ice. Besides the definite terminal moraines formed during the deglaciation of the area, scattered marginal deposits also occur frequently within the ground morainic tract. Ground and terminal moraines often merge into each other so that the two cannot be clearly distinguished. Gently undulating till-plains occur among hills of terminal morainic character.

The ground moraine occupies the northern and central parts of the area, merging gradually into the terminal morainic tract on the east, south and west. Many isolated symmetrical hills have altitudes from ten to twenty-five feet, rise with gentle slopes above the nearly level ground moraine, and are characterized in struc-

ture by a core of ordinary unassorted till surrounded and overlaid by irregularly stratified but fairly definitely assorted gravel and sand beds. The gravel is cherty and calcareous in composition, and the individual pebbles are not well rounded in form. Elevations of this character are so common as to be referred to as the "gravel capped hills" of the vicinity. The excavated summits and sides of these embossments of the till-plain at once reveal their structure, and mark their utility as a source of excellent road metal as well as sand and gravel for other constructive purposes.

The great body of the ground moraine is made up of a fine-grained, compact, aluminous clay, with which are intermingled grains of quartz, particles of silt, and angular fragments of the crystalline rocks. Widely scattered througout this clay matrix are pebbles, cobbles and boulders of various lithological characters not unlike those of the terminal moraines of this area, as elsewhere described. While the whole is unstratified as compared with the finite assortment of water deposited material, yet where sections of considerable thickness are exposed an irregular and crude bedding may be distinguished. Beds of varying thickness and attitude, consisting of definitely stratified sand and gravel, are interlaminated with the more massive and heterogeneous body of the till. The clay matrix is a dark, slaty gray in color, generally known as the blue clay of the region.

Oxidation has changed the upper five to twenty feet to a light yellow color. The thickness of the till sheet, as estimated from well records, varies from forty to 100 feet. Of the body of the till upwards of 90 per cent, both of the ground and terminal morainic tracts, seems to have been derived from the subglacial burden of the ice sheet. This material was supplied to the glacier from the underlying Cretaceous shales at no great distance from its present place of lodgement.

The very small number of boulders scattered over the ground moraine would seem to indicate that the superficial and englacial load of the glacier at the time of its resecession was relatively small. Almost all of the boulders are rounded masses of the more refractory fragments of the granitic and other crystalline formations which are found *in situ* 100 miles distant in the Canadian provinces to the northeast. Boulders whose characteristics point their origin to an outcrop of Palæozoic strata are found, but their number is exceedingly small.

Terminal Moraines.—The terminal moraines of the Tower quadrangle occupy the eastern southern and western portions. The broad, gently undulating plain thus inclosed in the northern and central parts, and which is drained by the Maple river system, constitutes the ground moraine, with, however, some marginal deposits, as elsewhere explained.

The eastern morainic tract enters the quadrangle from Ayr township in the northeast corner and passes southward through the center of Buffalo township to Howes township, where it bears slightly to the west, continuing thence south to the vicinity of the town of Enderlin. The morainic tract is about one and one-half miles in width, and includes the region of the Alice chain of lakes described elsewhere.

The northern third of this morainic tract has an altitude a hundred feet greater than that of the hills of its southern extension, and about sixty feet greater than the ground moraine and Maple valley to the westward. From these facts, together with the records of well borings, which show the drift to have a thickness of about sixty-five feet, it is apparent that this part of the moraine lies on the summit of a preglacial ridge.

The surface of the moraine is strongly undulating, the hills rising ten to twenty feet above the general level. Shallow undrained depressions are frequent. Farther south the hills are more widely separated and the slopes are less abrupt. A striking feature of the morainic deposits in Buffalo, Howes and Eldred townships, and also, though less conspicuqus, in Clinton, Pontiac and northern Binghampton and Springvale townships, is an arrangement of the hills and till ridges in short ranges having a definite north-northwest and south-southwest trend.

A type of hills or elongated elevations, whose structure and composition show them to be marginal deposits known as kames, occurs in the western portions of Buffalo, Howes, Eldred, Highland, northeast Liberty, western Moore, northern Thordenskjold, Norman, western Cuba and Alta townships. Two groups of these hills, which are typically developed and are used as a basis of description, occur in the southwest quarter of section 5 and the southeast quarter of section 8, Eldred township.

In structure these hills have an irregular stratification, and a fairly definite assortment of material, including sand and gravel, together with beds of bouldery till. The narrowing and widening

of the beds, crossed obliquely by delicately laminated stratification dipping at various altitudes and mingled with the coarser materials of the drift, indicate that both water and ice were concerned in their formation. The two groups referred to in Eldred township extend noticeably in a north-northwest and south-southeast direction, and this fact is general for the most of those that have an elongated form on the eastern portion of the quadrangle. Those in the four townships last named have no distinct axial trend.

Fergus Falls Moraine.—The western morainic zone varies from four to seven miles in width. It enters the quadrangle from the north through the central part of Noltimeier township, and passes due south to the eastern part of Fort Ransom and western Spring townships. Thence from the limits of the Tower quadrangle it continues southward close against the western bank of glacial River Ransom, maintaining its southerly course to the boundary of the state in range 58 west.

Mr. Warren Upham's sixth or Waconia moraine* lies seven miles distant to the west, while his seventh or Dovre moraine, as mapped, diverges from Bears Den Hillock to the southeast. The interruption in the morainic topography represented by "Sand Prairie" and the terraced region in eastern Bear Creek township is referred to under the history of the Sheyenne river.

The crest of the Fergus Falls moraine is represented by a main ridge extending from Noltimeier to Thordenskjold township through the central part of the western half of the morainic belt. It forms also the divide between the Sheyenne and Maple rivers. The ridge is continuous through a distance of nine miles in Norman and Cuba townships and its summit, a mile in width, presents a gently undulating topography with slight relief. In Alta and Noltimeier townships the crest is narrow and interrupted by deep sags, and hills with an altitude of twenty to sixty feet. Southward from northeastern Thordenskjold township the eroding waters of the glacial Sheyenne river where it crossed the moraine have left no traceable crest. Three culminating points, however, stand out in relief and mark the course of the moraine in this region, viz., (1) Standing Rock, a conspicuous elevation in section 6, Preston township; (2) a sharp drift ridge a mile in length in section 31, Preston township, and (3) Bears Den Hillock in Fort Ransom township.

*Upham, Warren, The Glacial Lake Agassiz. Mon. xxv, U. S. G. S., p. 143.

The last is the highest point of the continental divide on the quadrangle.

The outer face of the moraine is fairly well defined from Noltimeier township to the south part of Cuba township by the wide billowy topography and sandy structure of the Lanona plain. From Cuba township to the village of Oakville it terminates abruptly against the bluff of the Sheyenne valley and its heading coulees. Southward from section 26, Oakville township, through a distance of five miles the level plain of Sand Prairie replaces the western slope of the moraine. In Fort Ransom township the western slope merges into an outwash plain of sand and gravel declining gently to the drainage of Bears Den Hillock creek, one-half mile west of the border of the quadrangle.

The inner face of the moraine, from Noltimeier township to one and one-half miles west of the village of Fingal, presents a roughly rolling surface, the hills being closely aggregated and rising to an altitude of ten to fifty feet, and generally grouped into ranges having a north-south alignment. Many undrained depressions occur on this northern half of the moraine.

The morainic tract in southeastern Oriska, eastern Springvale and northern Binghampton townships, although standing in close continuity with the topography on Alta ridge, is to be correllated with a terminal morainal belt extending from western Oriska southeastward through central Springvale, Clinton and Pontiac to eastern Liberty township. In the northwestern half of this moraine where it diverges from the Alta ridge to the southeast, the hills and ridges of the drift have an altitude of fifteen to thirty feet, are closely aggregated and assume, with the intervening undrained depressions, a distinct north-northwest and south-southeast trend. A drainage channel from the front of this part of the moraine originates at the village of Fingal, southward through sections 20, 30 and 32, Binghampton township, and enters a branch of the Maple river in section 5, Raritan township. The southeastern half of the moraine, that portion in Binghampton, Clinton and Pontiac townships, presents a much less rugged type of terminal topography. The swells and ridges rise with gentle slopes to an altitude of twenty feet above the inner bordering plain. A few scattering elevations attain altitudes of twenty-five to thirty-five feet. Prominent hills with rounded contours and elongated form, showing the

water assorted structure of kames, are in this portion of the moraine closely associated with drainage channels.

From Fingal southward the eastern border of the main Fergus Falls moraine is ill-defined. The whole tract broadens out, the hills are scattered and low, ranging from ten to twenty feet in altitude, and separated by shallow undrained depressions and patches of low till plains. Some of the depressions assume the nature of steep sided pits from ten to thirty feet in depth and from a few rods to nearly a mile in diameter. Good examples of such marked depressions are found in northeast Preston township.

The Fergus Falls moraine as here described is understood to have been formed as a continuous series of deposits from the ice front when it lay along the slopes and crest of Alta ridge and southward to Bears Den Hillock in Fort Ransom township. While this belt of morainic topography in the western part of the quadrangle evidently marks one continuous marginal deposit of the glacier, the drift deposits themselves do not constitute so well marked a topographic feature that its boundaries are clearly and sharply defined. The exact location of these lines is in a measure arbitrary.

An Alternative Correlation.—An alternative correlation, strongly suggested by topographic relations and glacial drainage, would make the western moraine diverge in Thordenskjold township from its southward extension as above described, and bend away in a broad curve to the southeast, thus including the morainic belt extending through Moore, Liberty, Fuller and Casey townships. A part of the moraine extending into Shenford township and partly buried by the Sheyenne delta deposits is referred to later. From this point the moraine appears to curve southward and thence to continue in a southeasterly direction.

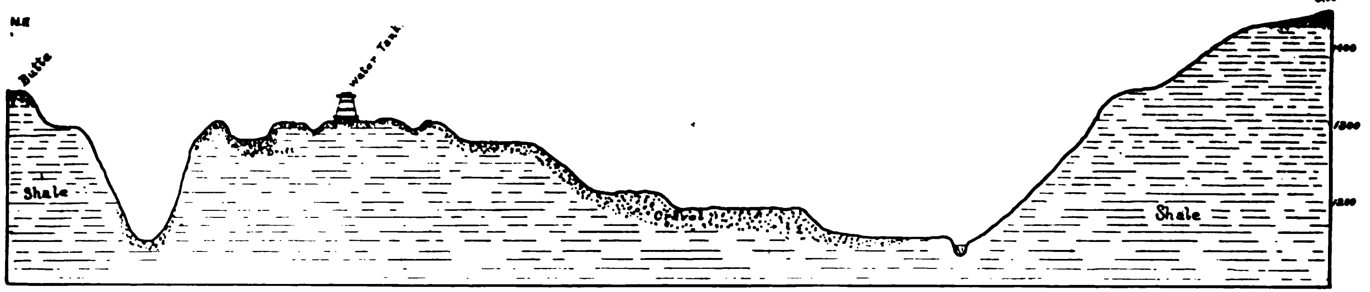
The western moraine is the principal terminal moraine of the area and is regarded as the southern continuation of the eighth or Fergus Falls moraine of Upham, from Alta and Noltimeier townships in the northeastern part of the area. Northward from the boundary of the quadrangle the Fergus Falls moraine traverses the townships of range 57 west, a considerable distance beyond the present area.

During his studies on glacial Lake Agassiz, Mr. Warren Upham traced his eighth or Fergus Falls moraine southward through Ayr and Buffalo townships, in the northeastern part of the quadrangle,

into the northwestern part of Howes township, thence westward in a broad curve through adjacent parts of Hill, Springvale and Binghampton townships, to Cuba township, thence northward through Alta and Noltimeier townships.*

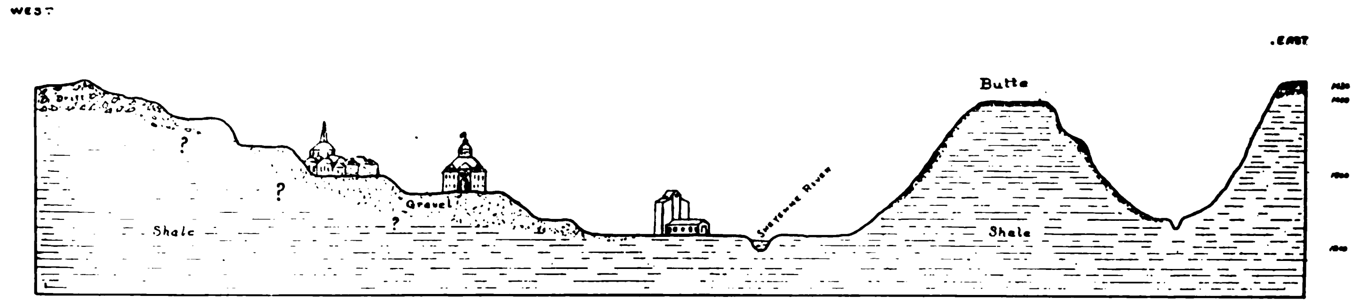
This mapping made the deposits define the southern end of a distinct narrow lobe of the ancient glacier, while the moraine in Norman, Thordenskjold, Raritan, Preston, Moore, Liberty and Casey townships was not mapped. The moraine on the west side of the Sheyenne river in Bear Creek and Fort Ransom townships, here regarded as the Fergus Falls moraine, was by Upham made to diverge thence sharply to the southeast and correlated with his seventh or Dovre moraine. The southern course of the Fergus Falls moraine, however, as traced by the writer, extends south from the limits of the Tower quadrangle through the townships of range 58 west.

*Op. cit. pp. 160, 161, pl. 17, et al.



(a) SECTION OF SHEYENNE VALLEY AT VALLEY CITY.

Section northeast-southwest across the bluff south of city, slightly generalized. At left are the butte east of the city and the coulee through which the Northern Pacific railroad descends into the valley. In center is the bluff on which stands the water tank, near which is an old channel by which the river once crossed. At right are the gravel terraces below the city, the river channel, and the west side of the valley, in which the shales are exposed. Observer looking south.



(b) SECTION OF SHEYENNE VALLEY AT VALLEY CITY.

Section east-west across north side of city, slightly generalized. At right are the butte east of city and the coulee through which the Soo railroad descends into the valley. In center are the river channel, the valley "bottoms" and the gravel terraces extending to the bluffs of the west side of valley. Observer looking north.

LATE GLACIAL AND POST-GLACIAL DEPOSITS OF THE SHEYENNE AND MAPLE RIVERS.

BY DANIEL E. WILLARD AND H. V. HIBBARD.

(By permission of the U. S. Geological Survey.)

Terraces and Deposits of Sheyenne River.—The Sheyenne river is bordered by teraces along much of its course through the Tower quadrangle. (See figure O.) The first and highest terrace formed is the nearly flat Lanona plain, which borders the valley continuously on the east, through adjacent parts of Noltimeier, Valley and Alta townships and the townships immediately to the south, southward to a point nine miles below Valley City. Farther south in Oakville township remnants occur on either side of the river represented by characteristically flat topped hills.

This highest terrace was the flood plain of the glacial Sheyenne river at the time the margin of the ice sheet was forming the morainal deposit on the Alta ridge, and its southward continuation in Preston, Bear Creek and Fort Ransom townships and southward beyond the present quadrangle.

This terrace, which is in places four to five miles in width, has been slightly dissected by subsequent erosion by the tributaries of the present stream, but through most of its extent in this area the original surface is little modified. The highest parts of the Lanona plain have an elevation of 1,420 feet above sea level, or more than 200 feet above the present Sheyenne river. Certain hills rising above this plain were surrounded by the waters which flooded the plain.

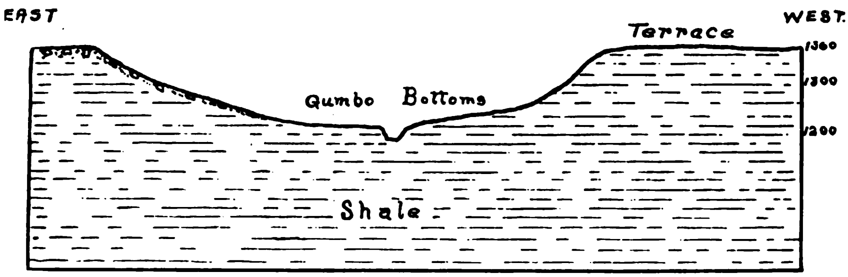
In Oakville, Bear Creek and Fort Ransom townships, is a broad nearly level plain, locally known as Sand Prairie, the surface configuration, superficial structure and composition of which indicate that it has been covered by a shallow body of water. In sections 2 and 11, Bear Creek township, the sand plain extends to the brink of the valley which is here 1,400 feet above sea level. Some higher portions of the plain have an elevation of 1,420 feet. Sand and gravel are reported in well diggings at depths of six to forty feet.

The sharply trenched modern coulees of the Sheyenne river, in sections 35, Oakville, and 2, Bear Creek townships, expose a continuous line of contact where sand and gravel beds, aggregating forty feet in thickness, are seen to rest upon glacial till. From well borings in the same and adjoining sections immediately west stratified gravel and sand overlie the till to a depth of fifteen to forty feet.

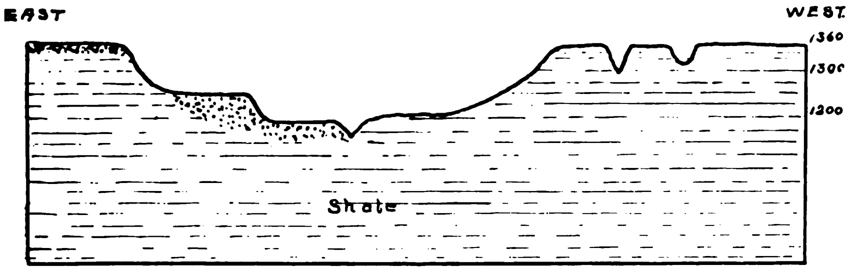
From these and similar data collected in the vicinity it appears that a deep sag in the underlying till plain extends from section 2, Bear Creek, west by south through a distance of perhaps three miles. This depression was doubtless eroded by the waters of the upper Sheyenne at the Lanona stage when the glacial drainage escaped by way of Bears Den Hillock creek. Later this channel was silted up to the present level of the Sand Prairie plain with the stratified deposits above referred to.

To the southward Sand Prairie merges into the broad bottom of the valley of Bears Den Hillock creek, by which it is connected with the plain of the bottom of glacial Lake Dakota. It reaches a width of about five miles in Oakville township, and has an average width of about three miles.

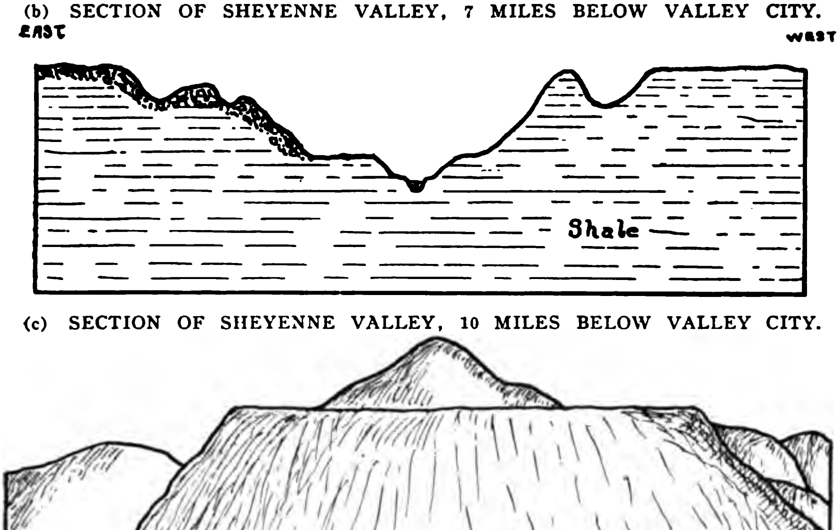
A second terrace, or ancient flood plain of the Sheyenne river, is represented by a flat plain which borders the valley on the west in adjacent parts of Bear Creek and Preston townships. This terrace, which has an elevation of 1,380 feet above sea level, or approximately 200 feet above the present stream, and an area of about four square miles, was formed after the ice front began its recession from the moraine on the west, and therefore marks a later stage of the river than that represented by the Sand Prairie and Bears Den Hillock creek channel. A well defined channel traverses this terrace from north to south through sections 12, 13 and 23, Bear Creek township. In section 26 and 35, Bear Creek, this channel has been much deepened and broadened by the later erosion of a deep coulee, but beyond this, in section 35, Bear Creek, and section 2 and 11, Fort Ransom townships, the ancient channel may be traced as a distinct trough-like depression high up on the steep side of the present Sheyenne valley, 186 feet above the present stream. Below Fort Ransom the present valley of the Sheyenne swings to the eastward, but the old channel continues southward in sections 11 and 15, Fort Ransom, and southward beyond the area under consideration. This channel, here a broad and well-defined valley, called River Ransom, extends southward close upon



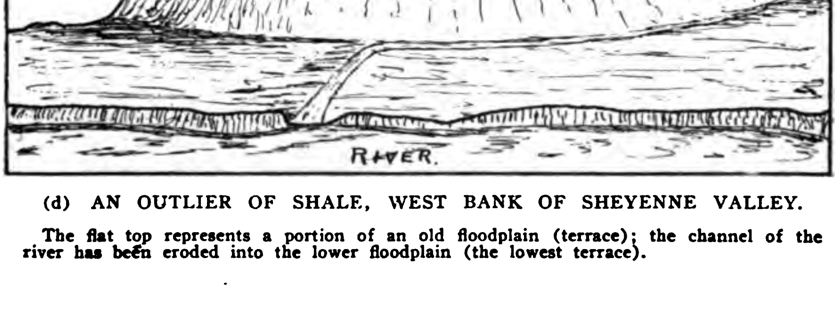
(a) SECTION OF SHEYENNE VALLEY, 3½ MILES SOUTH OF VALLEY CITY.



(b) SECTION OF SHEYENNE VALLEY, 7 MILES BELOW VALLEY CITY.



(c) SECTION OF SHEYENNE VALLEY, 10 MILES BELOW VALLEY CITY.



(d) AN OUTLIER OF SHALE, WEST BANK OF SHEYENNE VALLEY.

The flat top represents a portion of an old floodplain (terrace); the channel of the river has been eroded into the lower floodplain (the lowest terrace).

the eastern side of the moraine in range 58 west, and broadens out twenty miles south of this quadrangle upon the gently undulating plain of the bottom of a ancient lake in Sargent county known as glacial Lake Sargent.

Below the terrace just described is another at considerably lower level which is crossed by a channel from section 12, Bear Creek township, through sections 18 and 19, Preston township. The bottom of this channel is below the 1,360-foot contour and therefore twenty feet below the channel just described. It is probably represented farther north by traces on the valley slope in section 36, Oakville township, and by a slightly higher terrace in section 25 of the same township.

Below Fort Ransom remnants of terraces border the valley at intervals at successively lower levels, the descent being more rapid than the fall in the present stream, so that where the stream enters the basin of glacial Lake Agassiz the ancient flood plain reaches the level of the Sheyenne delta.

Other remnants of terraces at relatively lower levels, for example, two in sections 18, 19 and 30, Preston township, and in the vicinity of Valley City, represent later stages in the development of the valley.

At Valley City, near the point of entrance of the river upon the quadrangle, the river makes a sharp turn from a direction nearly southeast to west-southwest. On the inside of this curve an immense deposit of flood-plain scrool of gravel was formed. This is one of the most extensive deposits of gravel in the whole course of the valley upon the present quadrangle. It is marked by several benches or terraces representing stages in the development of the river valley. The principal one of these terraces is about fifty feet above the alluvial plain that borders the river. The Northern Pacific Railway Company has made extensive use of this gravel deposit as ballast for the roadbed, thus modifying the original form of the terrace. A part of the city is built upon the sloping surface of the terrace and this portion still preserves its original form.

Sections a mile in length have been cut through the deposit and these show it to be composed of stratified and cross-bedded gravel, sand and cobble stones downward approximately to the level of the alluvial plain. The greater part of the deposit consists of rather coarse gravel, but some interbedded sand occurs. Rarely boulders

are found. A thin soil, barely sufficient to sustain a scattering growth of grasses, covers most of the surface of the terrace.

Another finely developed terrace, comparable in height to the one just described, laps around and below the point of the bluff immediately south of Valley City, extending almost to the east bank of the river where the stream makes the wide detour to the westward.

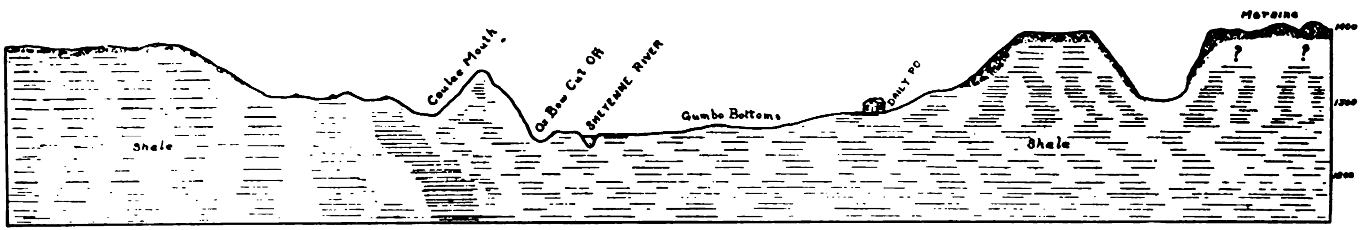
The broad bottom of the valley is covered with alluvium, the later floodplain deposits of the river while it yet received the drainage from the melting ice sheet and deposits formed during the present stage of the stream. The thickness of these deposits varies from four to twelve feet, as shown by wells and other natural and artificial excavations. Through this deposit the stream now meanders in a channel about twelve feet in depth. At some points the stream has cut away the alluvium and exposed the underlying shale. In many places beds of coarse gravel underlie the finer materials and where such deposits are encountered the bed of the stream is marked by slight rapids.

Many abandoned and silted up segments of channels persist in the tilled fields of the lowest terrace or floodplain. They usually present the form of ox-bows, and apparently when occupied by the stream were not essentially different from the present channel above which they lie at a height of eight to twenty feet. In the west half of section 17, and the east half of section 18, Preston township, are three concentric successively abandoned channels, all articulated with a sharp conformable bend in the present stream. The outer one of these three ox-bows traverses about three-fourths of the terrace between the bluffs. It lies about fifteen feet above the present river. At the upper and lower limits of such silted up reaches of the valley the recent stream is sinking its channel into new material, the beds of Cretaceous shale.

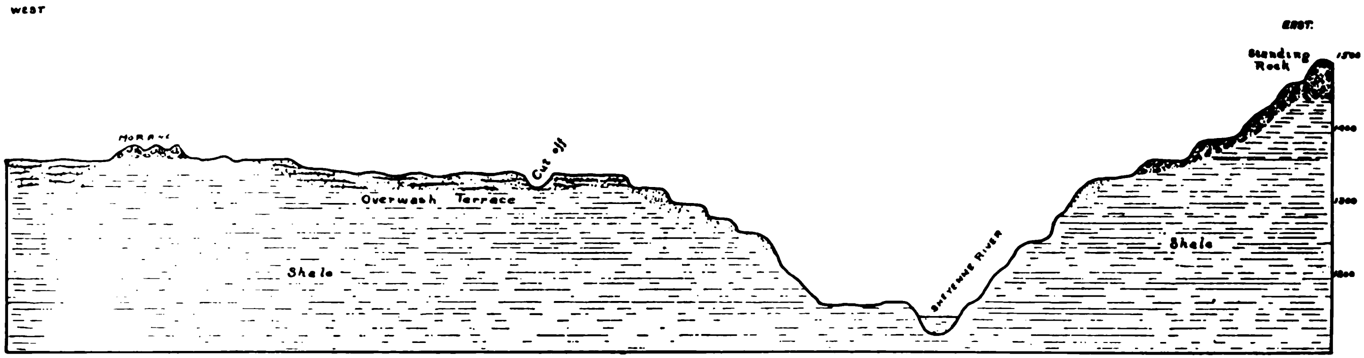
These aspects of the river and its lowest terrace indicate that an earlier stream, with tortuous windings and heavily burdened, deposited its load along the bottom of the valley in the form of a wide floodplain which the modern river has carved into terraces and is now steadily removing.

The texture of the alluvium from fine silt to coarse sand and gravel well stratified in all its exposures. The preponderating constituents are sand and silt, the latter dark in color, due to the associated organic matter. The organic matter together with the

PLATE VI.



(a) SECTION OF SHEYENNE VALLEY AT DAILY, 14 MILES BELOW VALLEY CITY.



(b) SECTION OF SHEYENNE VALLEY FROM STANDING ROCK SOUTHWEST.

21 miles below Valley City.

bitter salts from the shales, render the water of many wells on the river bottom lands unfit for use.

The Sheyenne Delta.—A tract of about twenty-five square miles of the deposits of glacial Lake Agassiz occupies the southeast portion of this area.

The shore line of Lake Agassiz enters the quadrangle in section 4, Highland township, passing thence southward to section 13, Casey township. The margin of the delta formation in Highland township, through a distance of five miles, is marked by a prominent ridge of irregularly stratified sand and gravel, the Herman beach or barrier. Southward through Sheldon and Casey townships the beach ridge is not well developed, the littoral deposits consisting of broad sheets of sand overlying the till. Northward from section 4, Highland township, through the marginal tier of sections to section 21, Howes township, the gently undulating topography and superficial structure indicate slight wave action and the presence of embayments of quiet waters outside, or west, of the Herman barrier beach during its occupancy by the lake waters. The altitude of the shore line through this quadrangle is approximately 1,085 feet.

The surface of sections 4, 5, 8, 9, 16, 17 and 20, Highland township, is flat. Throughout the remaining portion of the delta, except where deeply trenched by the Sheyenne and Maple rivers, the topography is very gently undulating. Slight ridges of dune sand occur in sections 17 and 20, Sheldon township.

The delta deposits vary in thickness from a few inches to sixty feet. In the southeast corner of the area the Sheyenne valley, here one-half mile wide and about fifty feet deep, is sunk into till or unmodified drift. The bottom of the valley is filled to a depth of ten feet with an alluvium of gravel and silt.

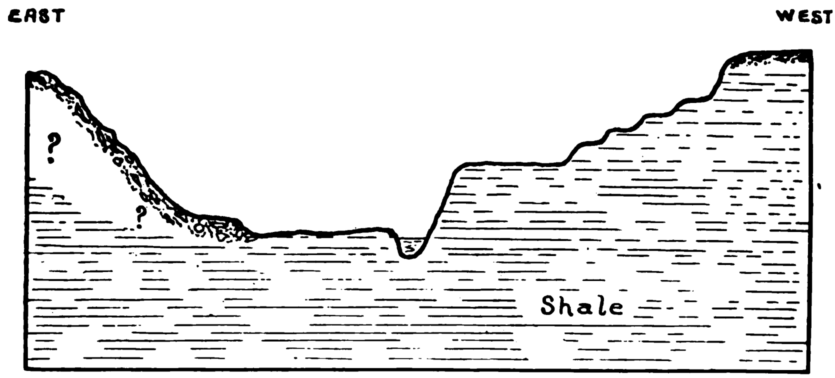
In Shenford and the adjoining parts of Casey, Liberty and Sheldon townships, glacial drift is exposed in many places at the surface. The delta deposits merely fill depressions between morainic hills. The topography and structure of this part of the delta plain is markedly different from that to the north in Highland and Sheldon townships. The elevations are rounded knobs and ridges with bouldery till exposed on the crests and flanked by water deposited sand and gravel. Numerous depressions bordered by slopes steeper than would be expected in such situations, lie among the

hills and ridges. Till is exposed along the sides of these pits, and their bottoms are built up with sand and silt.

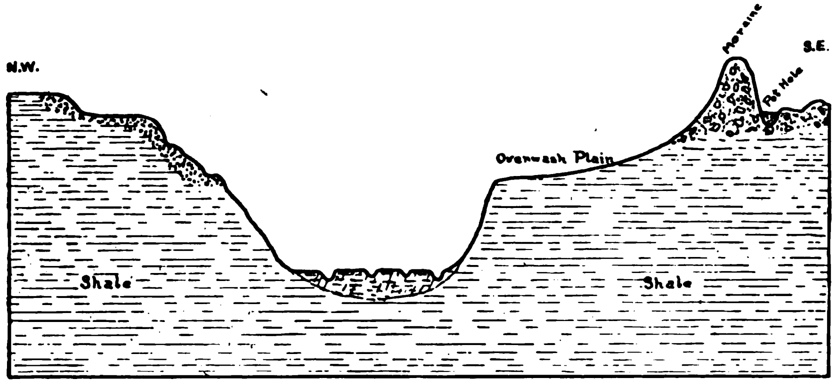
From these appearances it seems reasonable to conclude that a portion of a moraine provisionally correlated with the tract extending northwest to Thordenskjold township has in this region been inundated by the waters of Lake Agassiz. The morainic hills have been subdued and the intervening depressions partly filled by the waves and currents of the shallow waters covering the delta. Well borings on section 17, Sheldon township, penetrate twenty feet of stratified sand and reach stony clay beneath. A well in the bottom of Maple valley, section 31, Highland, is dug through sixteen feet of gravel to blue clay.

Terraces and Deposits of Maple River.—The valleys of the Maple river and its tributaries, within the Tower quadrangle, bear evidence of having been once occupied by streams much larger than the present small intermittent creeks. Extensive gravel deposits lie in the valleys, and well defined terraces occur at several places above the point in southwestern Highland township where the stream enters the basin of glacial Lake Agassiz. Good exposures of stratified gravel were observed at intervals in the main valley as far north as section 3, Clinton township. In section 15, Clinton township, a terrace which stands about ten feet above the bottom of the valley has a width of forty rods. One in section 22 is about thirty rods wide, and one in section 33 has a width of sixty rods. A well on a terrace in section 28, of the same township, penetrated eighteen feet of sand and gravel. In section 31, Clinton township, a terrace of shaly gravel occurs in a tributary valley. Below the junction of this branch with the main channel several good exposures of stratified gravel occur in terraces. Often a layer of alluvial soil a foot or two in thickness covers the terraces, but wells almost invariably show gravel and sand below. Sometimes, however, wells or other excavations on a terrace reveal clay material, probably till, showing the terrace to be one of erosion.

The city of Enderlin is built upon a gravelly plain which is about fifteen feet higher than the bottoms, or alluvial flat along the present channel of the river. About ten feet higher than the plain on which the city stands are other well defined gravel terraces, and the sides of the valley show pockets and shoulders of stratified sand and gravel at a level of thirty feet above the terraces.

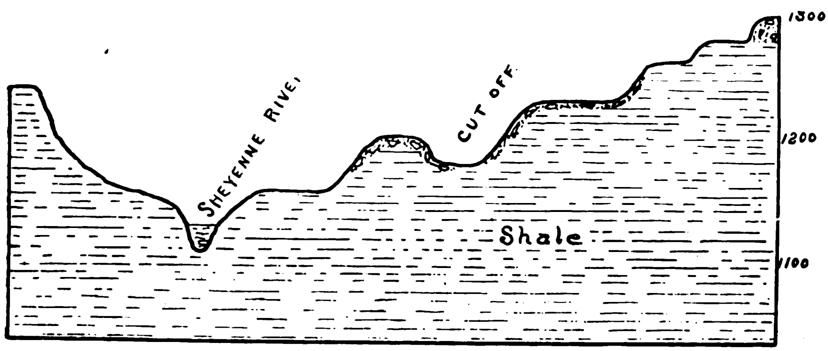


(a) SECTION OF SHEYENNE VALLEY, 13 MILES BELOW VALLEY CITY.



(b) SECTION OF SHEYENNE VALLEY AT "THE JAWS."

Section 36, Bear Creek township, 25 miles below Valley City.



(c) SECTION OF SHEYENNE VALLEY ABOVE LISBON.

The cut-off passes west of Lisbon about 2 miles.

In section 31, Highland township, and section 1, Liberty, the Maple river broadens its valley to a width of half a mile as it reaches the ancient delta plain of the Sheyenne. The highest or Herman shore of Lake Agassiz was probably near the western line of section 32, Highland township, though no beach is now traceable. Here till is exposed in the sides of the valley, the channel having been eroded below the lake deposits, but not so far as to reach the subjacent stratified shales.

GEOLOGIC HISTORY OF THE TOWER QUADRANGLE.

By Daniel E. Willard.

(By permission of the U. S. Geological Survey.)

PRE-QUATERNARY EVENTS.

Inasmuch as the only rock formations earlier than the glacial drift which are either exposed within the Tower quadrangle (see figure O) or encountered in drilling deep wells, are the shales and sand of the Cretaceous system, records of the earliest geologic events occurring here are not available. During later Mesozoic and Caenozoic times generally uniform conditions appear to have prevailed throughout the whole surrounding region, so that some inferences may be drawn from other areas. Wells at Fargo, thirty or forty miles east of this area, encountered granite at depths of 300 to 400 feet, immediately below the Cretaceous shales and sand, so that it is probable that for a long time prior to the incursion of the Cretaceous seas, land stretched far away to the eastward, and not improbably this land area included the Tower quadrangle. Its western limits are not known.

During the latter half of the Cretaceous period the waters of a sea reached across what is now the region of the Great Plains and the Rocky mountains as far west as the Wasatch range and extended from the Gulf of Mexico to the Arctic ocean. The incursion of the sea over this area was due to the relative sinking of the land. As the land slowly sank the waters advanced and the waves and currents washed and sorted the sediments brought down by the streams. The coarser sands and gravels were left near the shore, while the finer silts were widely distributed over the sea bottom. As the sea gradually deepened and the shore line advanced the silts covered up the sands. The sands were cemented together as sandstone and the silts were compacted into shales. Varying conditions caused more or less commingling and interbedding of sand with silts, so that frequent beds of sand or sandstone and of arenaceous shales are now encountered in drilling into the ancient deposits.

During the deposition of the Colorado and Pierre shales, marine conditions prevailed and the region was still further submerged until the shore line had been moved probably as far eastward as central Minnesota and Iowa.

The long duration of these epochs is indicated by the thick deposits of fine sediments which accumulated. At the close of the Cretaceous period the land permanently emerged and the sea never again covered the interior of the continent. Farther west large areas covered by fluviatile or lacustrine tertiary sediments, but no deposits formed during Tertiary time are found in this part of the state.

Probably during the Tertiary period the climate was much more warm and moist than now, so that the region abounded in animal and vegetable life. It is thought that during the latter part of the Tertiary period a large stream flowed southward somewhere near the present position of the James river. Doubtless tributaries of this or other streams drained the Tower quadrangle, cutting rapidly into the soft beds of shale and sculpturing the land surface into hills and valleys.

To the east was developed the broad ancient valley now traversed by the Red River of the North. The rapid westward rise of the present land surface in the western part of the Casselton quadrangle marks the location of the western slope of this great valley. This slope, formed by the cut-off edges of the Cretaceous strata, has been called the Manitoba escarpment. Within the area under discussion this escarpment is so mantled with drift that no exposure of the shale occurs, though the character of the underlying rock is revealed by well borings.

The Alta ridge is a broad, drift-mantled, preglacial ridge, extending two-thirds of the length of the quadrangle. It was probably fashioned by erosion during late Tertiary time. Whatever river valleys may have existed upon the ancient land surface within the area under consideration were now hidden by the thick mantle of drift.

QUATERNARY EVENTS.

Pleistocene Glaciation.—The opening of the Quaternary period was marked by a change in climatic conditions such that during the colder seasons snow fell in large amounts over a large part of northern North America. So great were these snow falls and so

meager, comparatively speaking, were the opportunities for their melting during milder seasons, that vast amounts accumulated over an area millions of square miles in extent. These conditions gave rise to the development of vast ice sheets comparable in character to the present ice cap of Greenland, but greater in extent. There apear to have been two centers of this accumulation, one in Labrador and one west of Hudson Bay. From these centers the ice moved out in radial directions with a movement such as is now observed in the mountain glaciers of various parts of the earth. The spreading of the ice sheet from these centers caused their coalescence, so that during the stage of their greatest extent a vast *mer de glace* covered the whole of the northern part of the continent southward approximately to the line of the Ohio and Missouri rivers. (Figure 3.) At this stage of maximum extension all that part of North and South Dakota lying east of the Missouri river was covered by this ice sheet, which was probably hundreds and perhaps thousands of feet in thickness.

As has already been indicated, the study of the deposits formed by these great glaciers shows that the glaciation of northern North America was not confined to a single stage of growth and decadence of the ice sheet. It appears that stages when the climatic conditions were favorable to the development of such continental glaciers alternated with milder intervals when the ice sheets wasted away, until large tracts previously covered with ice were again in condition for the return of animal and vegetable life. During these intervals soils were developed and new river systems sculptured the deposits of the glacial debris left spread over the land. The return of glacial conditions over most of the area previously glaciated destroyed many of the newly developed topographic features and buried the whole in a new deposit of drift.

Just how many successive stages of glaciation and deglaciation marked the region in which the Tower quadrangle lies is not certainly known. Some evidences of an interval of deglaciation have been considered elsewhere.

During the Wisconsin stage of glaciation the ice sheet in this region reached an extension shown in figure B. Northeastern Minnesota was covered by the Lake Superior lobe of the Wisconsin ice sheet. Sweeping southwestward and southward about the west end of this lobe another great glacier bifurcated at the head of the Coteau des Prairies into two great lobes, one of which, known

as the Minnesota glacier, passed from the broad ancient valley of the Red River of the North southeastward and then southward, traversing western and southwestern Minnesota and the north central part of Iowa as far south as the location of Des Moines. The other lobe, known as the Dakota glacier, moved down the James river valley on the west side of the Coteau des Prairies to the line of the Missouri river, spreading out on the west to and upon the Coteau du Missouri. The limits of these glacial lobes are marked by the Altamont terminal moraine. The Tower quadrangle is located about forty miles in a north-northwesterly direction from the head of the Coteau des Prairies, where the Minnesota and Dakota lobes separated.

The history of the advance of the glaciers of the Wisconsin stage is sketched here in the barest outline. Were it possible to learn them now, doubtless this advance would be shown to have been attended by many interesting events. As it is, but little more than the fact of the advance is known. When the ice melted away the debris borne forward in its mass and that accumulated at its base were left spread over the surface of the land as a mantle of drift, the bulk of which constitutes the ground moraine. To the action of these glaciers and their attendant waters, and especially to the deposition of the drift, is due in large measure the difference between that part of the state east of the Missouri river and the lands to the west, so that on the whole the glaciation of this region was a beneficial preparation for the advent of civilized man.

Deglaciation of the Region.—The progress of the final melting of the ice sheet which covered this region was marked by intervals of halt, or possibly even of readvance, as climatic conditions varied from time to time. The successive positions of the ice front during these stages of halt are marked by marginal accumulations of drift constituting more or less definitely ridged terminal moraines. The heaping up of drift in re-entrants on the ice margin, the pushing together of piles of debris, and the unequal settling of the deposits, due in part to the burial and subsequent melting of great masses of ice from the disintegrating glacier, resulted in the ridged, humpy and pitted topography characteristic of these moraines.

The Dakota glacial lobe which occupied the James river valley appears to have melted away somewhat more rapidly than the Minnesota lobe, so that the retreating ice front approached the Tower quadrangle from a westerly direction. The first marginal

deposit within this area indicating a check in the progress of glacial wasting is the moraine stretching across the western part of the quadrangle on the preglacial Alta ridge. The trend of this moraine shows that the ice front was retreating in a direction nearly eastward, and that at this time the western lobe of the ice sheet had almost if not quite disappeared.

At length another increase in the rate of wasting, a decrease in the rate of forward movement of the ice, or a combination of both, ensued, so that the glacial front was melted back from this terminal moraine.

As has been shown, morainal deposits, largely in the form of disconnected hills and ridges of stratified drift, are scattered over the whole area of the ground moraine east of the main moraine. The general trend of their axes seems to indicate a gradual shifting of the retreat to a more northerly direction, i. e., to a direction normal to the prevailing trend of these features. These character and distribution of these deposits suggests a general stagnation or disintegration of the ice sheet, affording opportunity for the assortment and localized deposition of the drift by streamlets on and near the melting ice. Many of these hills are typical kames and are thought to have been deposited by streams of glacial waters debouching at the ice front in re-entrant angles or crevasses and other cavities in the ice. The continued melting at length freed the Tower quadrangle from ice and in due time the whole continental ice sheet disappeared. Recent time for this area dates from the final disappearance of the glacier and of the waters resulting from its melting.

History of the Sheyenne River.—The melting of so vast an accumulation of ice resulted in great floods of water along the lines of all streams leading away from the ice front. The deposition of so great an amount of glacial debris over so large an area caused an entire rearrangement of the drainage system of the glaciated area. Old valleys were filled up and outflow of glacial waters established new streams which were gradually shifted from place to place as the ice fronts changed their positions, until the final disappearance of the glacial floods when drainage was established along present lines. This shifting of drainage lines is well illustrated by the streams of the area under discussion.

While the ice front stood at the moraine on Alta ridge and its southward continuation west of the river in Ransom county, glacial

waters here and from a considerable distance to the northward escaped southward along the western front of the moraine. The present Sheyenne valley not then having been excavated, this water followed sags in the surface of the drift, until it reached the James river valley by way of Bears Den Hillock creek. Since the Sheyenne river follows in a general way the course taken by these waters southward to Ransom county, this glacial stream may be conveniently referred to as the glacial-Sheyenne river. The floodplain of this stream has been described as the upper terrace bordering the Sheyenne valley. In the northwestern part of the quadrangle this is the Lanona plain, while Sand Prairie, in southern Oakville, Bear Creek and Fort Ransom townships, is its continuation. Between these tracts all but slight remnants of this ancient floodplain have been cut away by later erosion.

At this stage we may picture the glacial margin as resting on the ridge of debris on the Alta ridge, its surface rising at first rapidly, then more gently, stretching away to the east and north in a vast *mer de glace*. To the west was the drift plain recently exposed, its bare surface gradually becoming mantled with a new growth of vegetation. Near the glacial front was the broad river flowing southward to join the James river, its waters burdened with sand and silt brought to it from the neighboring slope of ice and drift by innumerable rivulets of glacial waters.

When the ice front was melted back from that part of the moraine in Bear Creek and Fort Ransom townships, a sag in the morainal crest allowed the waters of glacial Sheyenne river to cross to the east side of the ridge, where they found a lower outlet southward across the broad flat terrace described as occurring in eastern Bear Creek and western Preston townships. The ancient channel, known as River Ransom, formed at this stage, has been traced from section 12, Bear Creek township, southward across Fort Ransom township and beyond the bounds of this area. Continuing southward along the east side of the moraine twenty miles the stream mingled its waters with those of glacial Lake Sargent.

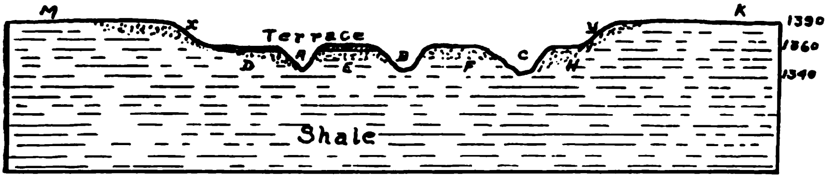
North of the point where it cut through the moraine the current had located itself approximately along the line of the present valley and began cutting downward. The bed of the ancient channel in eastern Bear Creek township has an elevation about 1,360 feet above the sea, fifty or sixty feet lower than the level of Sand Prairie, its earlier floodplain. The terrace in section 25, Oakville

township, corresponds in elevation with this ancient channel and may represent its northward continuation. With this also are perhaps to be correlated the cols or notches northeast and southeast of Valley City, which are marked on the map as old channels. With the deepening of the valley the notching of its lateral slopes by tributaries began, initiating the coulees now found.

That the deep valley of the Sheyenne is in its main features due to the eroding waters escaping from the wasting ice front as it lay along the summit of Alta ridge is evidenced by its tributaries rising from the eastern slope of the moraine, deeply trenched to a level with the alluvial plain, and showing in some cases an advanced stage in the development of terraces and river flats. Where the river departs widely from the moraine the valleys are wide and have developed terraces and broad river flats. Where the moraine stands close upon the shoulders of the valley the tributaries are short, steeply trenched coulees. Examples of the former are the valleys cut into the Lanona plain; of the latter those in the vicinity of Daily and six miles to the northward.

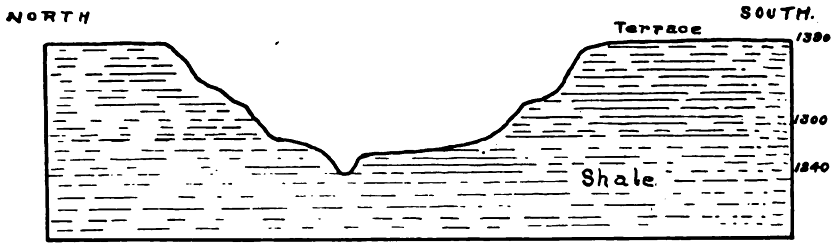
It seems likely that by the time of the formation of the moraine which extends from western Fuller township north by northwest through eastern Preston and Thordenskjold townships the river had abandoned the channel traced southward from Fort Ransom, as the general land surface to the east is as low as the bottom of this channel. The deep tributary channel known as Madigan's coulee, which extends from section 9, Spring township, northward to the moraine in eastern Preston township was the principal avenue of drainage from this portion of the moraine to the Sheyenne, which now followed its present course through Spring township. The broad terrace in sections 11, 12 and 13, Spring township, indicates that the level at which the waters ran was below that of the River Ransom.

The topography in Fuller and southern Moore townships is morainic in character, but it is not of the sharply rolling type such as commonly characterizes terminal morainic belts. The hills are subdued in form, less closely set than those of the morainic districts to the north and west. They appear to be a type of hills such as might be formed during a slow recession of the ice, when the ice edge was not quite stationary but slowly receding. Such condition of the ice front would have been sufficient to determine the course of the river in the direction of the line of the ice front.

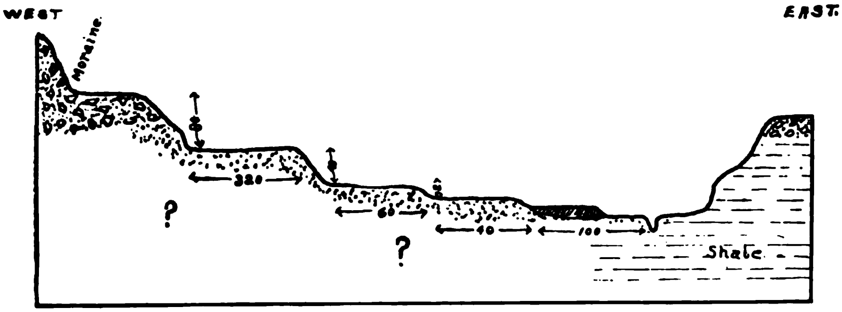


(a) SECTION NEAR HEAD OF GLACIAL CHANNEL.

Section 14, Valley township. A, B, C, coulees; D, E, F, H, gravelly terraces, boulders strewing their tops; K, M, adjacent prairie; xy represents the floodplain of the glacial stream.

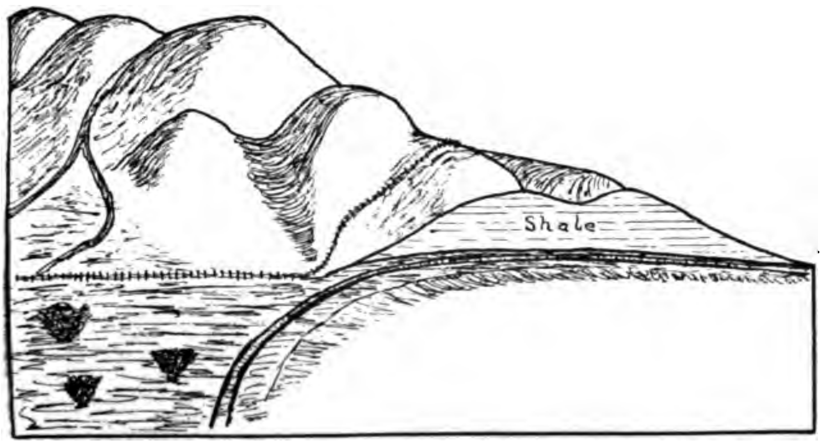


(b) SECTION OF GLACIAL CHANNEL ABOUT 1½ MILES BELOW (a).



(c) SECTION OF SHEYENNE VALLEY AT VALLEY CITY.

Generalized section from the butte east of city northwest about 2½ miles, through sections 22, 21, 16, 17, Valley township.



(d) RAILROAD CUT EAST OF KATHRYN.

Shale shown at *right*, and the terrace floodplain continuous with this at left.

The trend of the moraines to the south beyond the present area is in a generally south-southeasterly direction.

A point about three miles above the bend in the river at Fort Ransom, in section 36, Bear Creek township, is the narrowest and most canyon-like in the whole extent of the river on this area, and probably in its whole length. It is locally known as the Jaws. This is interpreted to be the place where the river crossed the axial part of the moraine, and thus is explained the narrowing of the valley in this portion of its course, and the increase in the fall of the river's bed below. The valley slopes and the channels eroded in the alluvial plain show a larger constituent of boulders in this narrower portion than elsewhere in the valley. From this time is marked the shifting to the eastward of the divide which now separates the Gulf drainage and that to Hudson Bay.

From this time the stream followed its present course to the point where it enters the basin of glacial Lake Agassiz, about ten miles south of the southeast corner of the Tower quadrangle.

Glacial Lake Agassiz is the name given to the body of water which flooded the broad basin of the Red River of the North as the Minnesota glacial lobe was melted back to the northward. As the ice front retreated the area of ponded waters was extended until they encroached on the southeastern part of the Tower quadrangle in the townships of Highland, Sheldon, Shenford and Casey. Where recognizable in Highland township the elevation of the highest or Herman shore line of this glacial lake is approximately 1,085 feet above the sea, so that that part of the Sheyenne river valley within the Tower quadrangle may have been eroded to its present depth while yet the stream discharged its waters into this lake. The material derived from the erosion of this valley, together with much glacial sand and silt contributed by the drainage from the melting glacier, was spread out upon the lake bottom in the great delta deposit to which reference has already been made.

Glacial Lake Agassiz discharged by the way of Lake Traverse, Big Stone Lake and Minnesota river valley until the glacial front had been so far melted back that a lower outlet to Hudson bay was opened. During this time the water sank to lower and lower levels, with the cutting down of the southern outlet, and with the lowering of the lake the Sheyenne river was extended across its delta deposit to the retreating shore line. In this way the stream reached the southeast corner of the area under discussion, where

it now flows through a sharply cut valley about fifty feet in depth, eroded in its early delta deposits and subjacent till. With the final disappearance of glacial Lake Agassiz the stream became tributary to the Red River of the North.

The erosion of the Sheyenne valley was practically completed before that of the tributary valleys, and probably while yet it received the drainage from the melting ice in this area and to the northward. This is shown by the occurrence of alluvial fans or aprons of gravelly material sloping from the mouths of the tributary valleys toward the axis of the main valley, which deposits have been dissected by the streams now flowing in the valleys. This material was derived from the erosion of the coulees and possibly direct from the drift at the melting ice front. As the deepening of the valleys continued the streams cut through the deposits previously made. Generally these valleys are much out of proportion to the rivulets which now flow through them.

History of Maple River.—Maple River has a history somewhat similar to that of the Sheyenne in its relations to the shifting of the ice margins. Extending from a point northwest of the village of Fingal in a southeasterly direction to the southwest corner of Pontiac township is a channel in whose bottom and banks gravel is exposed. In section 26, Raritan township, a similar channel joins this from the west. Other channels lead from these to the channel in Moore township, now occupied intermittently by the south branch of the Maple river. This latter channel, though traversed by very little water except in the spring season, is well defined, with abrupt slopes thirty to forty feet high in northern Moore township and fifteen to thirty feet high in southern Moore and Fuller townships. It is continuous from the village of Enderlin to section 20, Fuller township, where it reaches the Sheyenne valley as a hanging valley about seventy-five feet above the present stream. At present but one or two miles of this channel drains to the Sheyenne river. Throughout much of its extent the bottom is fine level meadow, the divide being imperceptible to the naked eye. These channels appear not to be due to recent erosion, and their existence leads to the inference that they were formed by the discharge of glacial waters to the Sheyenne river while yet the glacier extended west of the present main valley of the Maple river.

The low channels in Raritan township and the course thence to the Sheyenne river may represent the first two stages in the development of the Maple river. A third may be represented by a discharge southeastward by way of the valley heading in eastern Binghampton, through Pontiac township to Enderlin, and thence by the valley of the south branch to the Sheyenne river. A fourth stage, still discharging to the Sheyenne, marked the opening of the main channel and upper tributaries to the vicinity of Tower City. A fifth stage resulted when the ice still further receded, opening the channel east of Enderlin. The waters of glacial Lake Agassiz encroached upon the quadrangle and the stream discharged into this lake. This resulted in a reversal of the drainage in the valley of the south branch and the abandonment of the outlet by this channel to the Sheyenne river. Probably as long as the ice front stood near its head while the stream was discharging into the lake, contributions of glacial sediments were made to the great delta of the Sheyenne river, but when the ice entirely disappeared from the region and the lake was lowered by the cutting down of its outlet, this stream also was extended across the delta to the retreating shore line, and its channel in the delta deposits was eroded. The stream now joins the Sheyenne river northwest of Fargo, thirty miles east of Buffalo.

NOTES ON THE WATER SUPPLY OF A PORTION OF CASS, BARNES AND RANSOM COUNTIES.

By Daniel E. Willard.

(By permission of the U. S. Geological Survey.)

ECONOMIC GEOLOGY.

Water Supply.—Two of the most important consfderations in an agricultural section are those of water supply and soil. Without the former the most advantageous use cannot be made of the resources of the latter; and the most abundant and pure water supply finds its fullest use and value in a region in which agriculture is one of the leading pursuits. The Tower quadrangle is located in a region in which agriculture in some of its varied aspects seems destined always to be the foremost industry.

The water supply of any region may be considered under two divisions, viz., surface waters, or those derived directly from rain fall or melting snow, in which may be included all waters that have penetrated the earth in the immediate vicinity from which they are obtained; and underground waters, or those which are obtained from sources below the surface, and which are derived from precipitation that occurs at a greater or less distance from the local supply. The surface waters of the present area which require consideration are streams, lakes and ponds, springs and shallow or surface wells. The underground waters include tubular and artesian wells.

Streams.—The Tower quadrangle is crossed by the Sheyenne and Maple rivers, the latter having also several intermittent tributaries. These streams, however, furnish but a small fraction of the required water supply for the area for agricultural purposes, and are entirely unfit for domestic use. The comparatively few residents who are situated near the streams often are able to obtain the necessary supply for stock and laundry purposes from the rivers, but the water is not good for drinking or culinary purposes. Use is however often made of springs that well out upon the

steep banks of the valley sides, or to shallow wells dug in the gravelly or sandy floodplain deposits of the valley.

Springs.—Springs occur along the whole course of the Sheyenne, on this quadrangle, and along the deeper channels of the Maple and its branches. Springs are of very common occurrence in the Sheyenne valley at the horizon of contact between the shale and the drift. Springs, however, furnish no considerable part of the water supply of the quadrangle. Their occurrence and distribution are such that they are available for practical use to only a few who live in the valleys, and then the quantity of water furnished by such sources is inadequate for the demands of house and farm.

Lakes and Ponds.—Many small lakes occur upon the quadrangle, but they are of little importance as sources of water supply for either agriculture or domestic purposes, owing to the mineral matter in solution. Few if any of the lakes on the quadrangle contain water suitable for stock to drink. Many of these bodies of water contain so much alkaline and other salts that little vegetation grows about the lake basins within the area reached by the waters.

Shallow Wells.—Surface wells are of local importance only. In a few places surface conditions are such that wells a few feet in depth furnish the necessary supply both for farm and domestic uses. Water is obtained in abundance from wells twelve to eighteen feet deep upon the Lanona Plain east of Valley City; on the lowland west of Oriska, bordering the Alta ridge at from sixteen to twenty-four feet; on the sandy plains of the Sheyenne delta in the southern corner of the quadrangle at from eight to sixteen feet; and on Sand Prairie in the southwestern corner of the quadrangle at six to ten feet. In these locations surface conditions are such as to favor the ground water table being near the surface. In all these cases the water penetrates the soil at or but a short distance away from the source of supply.

As a general rule the waters from surface wells on this quadrangle are not of superior quality, owing to the presence of alkaline salts derived from the soil through which the waters have percolated. There are noteworthy exceptions, however, to any general rules regarding the qualities of the well waters of the area. The shallow wells of Sand Prairie yield water of an exceptionally pure quality as well as unlimited supply. The shallow wells in the sandy pain of the Sheyenne delta also furnish water of very superior quality. On the other hand the waters obtained from surface

wells in the district east of the Alta ridge and also that of the Lanona plain nearer the highland of the Alta ridge, is not of excellent quality, though variable within very short distances. Some shallow wells along the east foot of the Alta ridge yield water that is so strongly alkaline as to be of little use for domestic purposes and similarly on the west side of the ridge, bordering the Lanona plain.

The explanation of these differing conditions is probably to be found in the underdrainage of the soil in which the wells occur. The flat plain of Sand Prairie has been referred to above as a plain over which the waters of the Sheyenne river passed during its earliest stage. The surface soil is underlain by sand and gravel, assorted and washed by the glacial river, and it is from this substratum of sand and gravel that the water supply is obtained. No wells have penetrated below this sand and gravel stratum, owing to the fact that so abundant supplies of water are obtained in the sand and also to the fact that the sand and gravel cave in so that it is impossible to excavate to a depth or more than a few feet. The character of the subjacent rock is therefore not known with exact certainty based upon observation. It may, however, be pretty safely assumed to be clay, either boulder clay or the clayey upper layers of shale. The topography being nearly level, the underlying clay serves as a dish to restrain the water from percolating downward. This fact makes the shallow wells possible. The general slope of the plain is such as to allow a slow percolation of the underground waters by which the sand and gravel are situated. To this underground flowage, with the added circumstance that the nearly impervious clay below permits of no considerable capillary movement of water from below, is attributed the freedom from the shallow well waters from alkaline and other salts.

In the same way the waters from shallow wells of the Sheyenne delta are almost free from foreign salts. The loose texture of the delta material allows the ready penetration of waters from the surface, and the lateral movement of the waters is sufficient to prevent the concentration of salts. Some wells of the Lanona plain are similarly free from foreign impurities, and due to the same cause, viz.: the lateral movement of the underground waters by which the salts are carried away.

At Lanona station a well about fifteen feet deep furnishes water in practically unlimited amount, but of very poor quality. The sub-

soil of the surrounding region is clayey, and the topography is such hat surface waters cannot easily except by evaporation or percolaion into the soil, and the structure of the plain here is such as not o afford ready lateral underground drainage.

On the east side of the Alta ridge a great variety in quality of vaters is observed, due to the varying conditions of the under soil. Where wells are reported from gravel beds of considerable thickness the water is generally of good quality. Where, however, the gravel or sand layer is thin or where blue clay is reported in close connection with the water bearing vein, the result is almost invariably an alkaline water supply.

TUBULAR WELLS.

Occurrence.—One of the principal sources of the water supply of the quadrangle is the bored or tubular wells. These wells range in depth from forty to 150 feet. They differ from common or surface wells in that the water is derived from rain that penetrates into the earth at some distance from the location of the well. The water often rises in these wells nearly to the surface of the ground. In some cases reservoirs have been excavated about the mouth of the well into which the water flows and is pumped out from this reservoir. On section 17, township 136 north, range 56 west, Moore township, after repeated unsuccessful attempts to get a sufficient supply for general farm and household purposes by digging and boring, a tubular well thirty-two feet in depth, located at the top of a round knob-like hill, furnished an abundance of water which rose nearly to the surface. A horizontal pipe was attached and a trench cut in the hillside to convey the water, and a running stream was thus delivered to a milkhouse and stock trough. Another well about four miles east flows over the surface at some seasons of the year and at others requires to be pumped. Both wells furnish inexhaustible supplies.

Shallow Flowing Wells.—A well on section 11, township 140, range 55, on the farm of Senator Frank Talcott, is thirty-two feet deep and flows a constant stream. Several wells of this character ranging in depth from twenty-five to forty-eight feet, occur along the Maple river in townships 139 and 140, range 55 west.

The flow of these wells is determined evidently by the local topography. Many springs occur along the valley of the Maple and its tributaries, the water being conveyed underground from the

higher porous soils in the nearby region to the valley where it breaks out along its banks and bottom. Springs of constant flow on the sides of the valleys and pools that well up through the gravels of the valley bottom are closely related to the class of flowing wells just described. The land surface three miles east and five to six miles west of the flowing wells referred to is sixty feet higher than the prairie along the river, and still higher farther west. The gathering ground is therefore sufficiently extensive to permit of a constant flow from the tubes that penetrate these veins. These wells have been flowing for a period of something like ten years and the constancy seems undiminished.

Wells of very similar character, called Pleistocene artesian wells, occur upon the territory adjacent to this quadrangle to the eastward where the land surface slopes toward the Red River of the North on the western side of the Red River Valley and also on the eastern side of the Red River Valley east of the Fargo quadrangle in Minnesota. These latter wells owe their existence and pressure to the fact of the higher porous gathering grounds on either side of the Red River Valley and the conveyance of the water underground beneath heavy layers of clay.

Structure.—The tubular wells may or may not penetrate below the mantle of drift. In either case the compact blue clay which overlies the water vein serves as a restraining stratum underneath which the waters are conveyed for some distance from the porous soils where they penetrate the ground. When the clay is pierced by the drill or auger the water rises often with considerable force till the hydrostatic level is reached. The sandy or gravelly stratum along which the water is conveyed, and which is penetrated in the process of boring is porous enough so that the water readily passes through it. This stratum is sometimes probably a layer of sand or gravel which lies at the contact between the drift and the underlying rock, and sometimes it is thought to represent a layer of sand or gravel in the underlying Cretaceous rocks.

Quality of Water.—Frequently these wells furnish water that is palatable and wholesome when the water is freely used so that the supply is kept renewed by constant pumping, but becomes brackish and stale, often acquiring a disagreeable odor and taste, and acquires chemical properties that render it unfit for domestic uses, if allowed to stand in the tube of the well. This undesirable effect probably comes from the action of the water, which generally contains some

alkaline or other salts, upon the clay in which the tube has been made. When the water is allowed to stand in reservoirs or cisterns excavated about the mouth of the well, or when the well was dug in part and then a boring made to the water vein, the effect upon the water thus stored and kept standing is generally bad. This trouble can generally be overcome largely by the use of windmills, when the water can be kept fresh by constantly drawing out so that the supply is kept ever renewed.

Source of the Water.—Many tubular wells penetrate the shale which underlies the drift, though the exact horizon between the blue clay of unoxidized drift and the blue clay of the stratified series below is frequently able to be determined only with some difficulty. The driller often refers to the "soapstone," which is interpreted to mean the shale-clay that underlies the drift. In some localities good wells are obtained from layers of sand in the "soapstone" or shale, but it is frequently contended by drillers that when no water vein is struck before reaching the soapstone that none will be found. And this is true is some regions.

The region along the crest of the Alta ridge is one in which few wells of good capacity and quality have been found. The drift mantle is not deep and there is not an extensive collecting ground. Subterranean reservoirs for storing and conveying the waters which fall upon the land seem to be very scant. Along the foot of the steeper sloping sides of this ridge abundant supplies of water are obtained at shallow depths. These appear to be supplied from the higher land on the ridge. The ridge itself is a preglacial hill, of probably Pierre shale. The crest of this ridge is 200 feet higher than the plain ten miles eastward about Tower City, and nearly 300 feet higher than the bottom of the Sheyenne valley, six miles westward. The conditions, therefore, seem to be unfavorable for tubular wells in this region, and relief is to be looked for in the deeper artesian wells.

NOTES ON THE WELLS OF A PORTION OF THE DAKOTA ARTESIAN BASIN.

By Daniel E. Willard.

(By permission of the U. S. Geological Survey.)

Extent of Area.—So far as tests have been made it seems fairly safe to predict that successful artesian wells can be obtained in most parts of the Tower quadrangle. From a study of a structure section of the area it will be seen that the water-bearing Dakota sandstone lies at progressively greater depths westward, being encountered at 500 to 600 feet along the eastern side of the quadrangle, and at increasing depths westward to 1,070 feet in the southwest corner of the quadrangle, and at 875 feet in the bottom of the Sheyenne valley at Valley City, on the western edge of the quadrangle. It should be borne in mind that the bottom of the Sheyenne valley is 200 feet below the general prairie level, and nearly 300 feet below the crest of the Alta ridge. The altitude of the surface in the southwestern corner of the quadrangle, where a good flow was obtained at a depth of 1,070 feet, is 1,460 feet above sea level, the well being upon a bluff immediately overlooking the deep Sheyenne valley at Fort Ransom. The surface is therefore about 350 feet at the well in the southwestern corner of the quadrangle, and the prairie level about Valley City is nearly 300 feet higher than the surface in the neighborhood of Buffalo where several borings occur, on the eastern portion of the quadrangle. The depth to the water-bearing sand rock increases from 500 feet near Buffalo to 1,070 feet near Fort Ransom. Along the line of the Northern Pacific railway from Buffalo to Valley City the increase is from 500 feet to 875 feet in the valley bottom, or 1,075 feet below the general level. Thus the increase in depth is seen to be greater than the increase in altitude, showing a westward dip of the water-bearing sand rock from Buffalo to Fort Ransom of 210 feet, and along the line of the Northern Pacific railway from Buffalo to Valley City of 275 feet. The altitude of the highest part of the Alta ridge is 1,500 feet. It thus seems reasonable to predict that flowing waters can be obtained along the crest of

he Alta ridge, in the northwestern portion of the quadrangle, at a depth of approximately 1,150 feet, and farther south along the axis of this ridge at slightly lesser depths. A well that has recently been completed in section 4, Alta township, at a depth of 1,160 feet is reported as yielding no flow, the water rising within sixty feet of the surface. The water has the salty quality characteristic of the artesian waters of this basin.

Character of the Water.—The water from the artesian wells of the Dakota sandstone is slightly salty in character in all cases observed. The water is generally of suitable quality for culinary and domestic purposes, and when its use has become habitual it is often preferred to the waters from other wells. It is generally liked by farm animals, and they are found to thrive upon it. It has not yet been demonstrated in this region that the waters can be successfully used for irrigation purposes, but comparatively few trials have been made. Several cases have come under the writer's observation where the water has been applied to flower and vegetable gardens and lawns. Good results have followed in nearly every case observed. Tender foliage is found to suffer sometimes when the water is sprayed upon the leaves, the injury apparently arising from the effects of the sun upon the salt covered surfaces. In some cases where the water flowed over the surface in considerable quantity, or where the soil became saturated with the salty water without adequate drainage, grass and other vegetation suffered. As a general thing the usableness and value of the water for general agricultural purposes is beyond question. In a region where agricultural interests are paramount the value of the artesian water resources can hardly be overestimated. Experiments have not been made extending over sufficient time to demonstrate the practicability of the use of the waters for general irrigation purposes.

Constancy of Supply.—Of the constancy of the supply there seems to be no ground for reasonable doubt. No diminution in the pressure or flow that can be traced to a lessening of the supply has been noted. Where wells have failed or grown feeble in delivery of stream it has been probably due to faulty construction in the well, causing or permitting infiltration of sand. If it is true, as is generally supposed, that the water comes from far away upon the flanks of the Black Hills and the Rocky Mountains, this immense gathering ground would seem to leave little ground for

alarm lest the supply be exhausted. No apparent diminution has been noticed by the increase in the number of wells.

Power From Artesian Wells.—Little use has been made in this region of the pressure of artesian waters for power. Only in one instance in the present quadrangle has the power been utilized for propelling machinery, which is in the blacksmith and wagon shop of Davidson Brothers, Valley City. Here the pressure is about sixty pounds per square inch, or the equivalent of four to five horse power, and it is considered well worth the cost of construction of the well. It has been suggested that the power from artesian wells might be utilized for lifting water from the Sheyenne river for irrigation purposes up to the lower slopes and bottom lands of the broad Sheyenne valley.

Pressure of Wells.—Pressures range from forty to sixty pounds per square inch upon this quadrangle. The well of Davidson Brothers at Valley City, which is a four-inch well, showed a pressure of forty-five pounds when first drilled, but has increased within a year to sixty pounds. A well recently completed at Enderlin is reported by the driller to have a pressure of 175 pounds. The well in the cemetery at Lisbon, four miles south of the Tower quadrangle, in section 2, township 134 north, range 56 west, is reported to have a pressure of ninety-two pounds per square inch. The well at the Soldiers' Home, Lisbon, located on the valley bottom of the Sheyenne, fills the storage tank ninety feet above the surface of the ground. The city well at Lisbon, located on a terrace bench of the Sheyenne, estimated to be fifty feet or more above the river, throws a vertical stream sixteen inches above the mouth of the pipe. Other wells in the region about Lisbon show pressures ranging from forty to 120 pounds. A well recently completed at Enderlin is reported by the driller to have a pressure of 175 pounds per square inch.

THE SOILS OF THE TOWER QUADRANGLE.

By Daniel E. Willard.

(By permission of the U. S. Geological Survey.)

Geologic Relations.—The soils of this quadrangle (see figure O) are such as have been formed, either directly or indirectly, by the action of the great ice sheet. The soil types in the different parts of the area conform to the geologic conditions under which they have been formed. The proper study of the geologic structure of the soils is therefore one of the most important and fundamental in the development of the resources of this region.

The soils of the quadrangle may be grouped into three classes for convenience, and the more particular study of the different types will be found to accord with this general classification. These three types are, (a) those that have resulted from the materials deposited directly from the melting ice of the great continental glacier and include the characteristic soils of the morainic areas, recessional deposits, and the soil of the rolling prairie or ground moraine, usually a silt loam resulting from the grinding processes of the great ice mass; (b) those the form and character of which have been determined indirectly by the great ice-sheet and whose particular structure is the result of deposition from waters from the melting ice-sheet either from running streams or from still bodies of waters such as lakes, and (c) those soils which have been derived directly from the disintegration of the shales where these are exposed at the surface.

Soils Deposited Directly From the Ice.—The soils of this group, as already indicated, are of three general types, morainic, recessional and silt. The morainic deposits are not infrequently somewhat stony, though cases where there are boulders large enough in size or abundant enough in quantity to render the land unprofitable for cultivation are rare on this quadrangle. It is often the case that the higher portions of the morainic lands are so drained because of their position and greater looseness of texture, owing to the removal of the finer portions by rain wash, that they are

less valuable for agricultural purposes, but most of the morainic hills are capable of cultivation—in marked contrast with the earlier moraines in some sections to the westward.

Corresponding with the higher places in a morainic tract are the ever present sloughs or small lakes. While the topography of the Tower quadrangle is morainic it is not generally strongly so, and the waste land due to small lakes and sloughs is not nearly as great in amount as in many morainic regions in the state. In many cases valuable hay meadows and pasture lands are afforded on the bottoms of these depressions. The type of hills which has been referred to as recessional deposits play an important role in the classification of the soils. In the localities where these deposits occur the soil is generally a sandy loam varying to gravelly loam. The subsoil in these deposits is generally sandy or gravelly, it having been elsewhere observed that the structure in these deposits is usually that of definitely stratified sand and gravel with an admixture of clay. The soils on these ground swells is therefore light in character and not the most suitable for crop production. These hills afford the finest places for building sites, owing to the excellent sanitary conditions that are provided by nature. Often, also, the best well water is obtained by boring upon such hills. It is in many cases the fact that water of good quality and abundant quantity is obtained from wells on the hills when a few rods away on the surrounding low land only water of poor quality, alkaline in character and small in amount, can be obtained.

The soil type that embraces the greater part of the qudarangle is a silt loam varying to sandy loam, which is the soil upon the surface of the glacial deposits which composes the generally nearly level or undulating land surface. The character of this soil is determined by the character of the drift from which it is derived, and the character of the drift is determined by the kinds of rock which the great ice sheet passed over. The rock beneath the drift in this region and the adjacent region to the northward is shale, which disintegrates into clay, and the soil is therefore somewhat clayey in character. The silt probably has been derived from the grinding to powder of the hard rocks which were carried by the great ice mass.

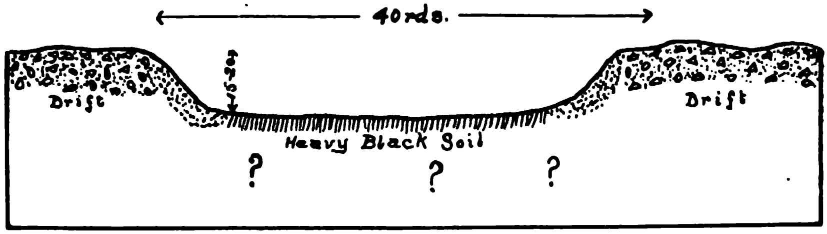
Stream Deposits.—Stream deposits on this quadrangle are mostly represented by materials that were transported by running waters of vastly greater extent than any that now exist upon the

uadrangle. Modern stream deposits occur upon the low bottom inds of the Sheyenne valley along the course of the sluggish ieandering stream that now occupies the great valley, and alluvium lso has been deposited by the main stream of the modern Maple ı the lower portion of that part of its course included in this area. 'he more extensive stream deposits of both the Sheyenne and Iaple valleys were left from the flood waters of the glacial treams. River gravel, which may or may not be covered by alıvium, occurs upon the bottom of the Sheyenne valley, and parts f old flood plains represented by gravelly terraces, mark the deosits of earlier stages of the river. River gravel also occurs along he bottoms of the Maple and all its tributaries, and gravelly teraces occur along the main stream of the Maple from the southern art of Hill township southward to the debouchure of the valley pon the plain of the bottom of Lake Agassiz.

An important soil feature in the Sheyenne Valley is the material hat has been carried in by lateral tributaries and distributed in the orm of alluvial fans, or washed down the sides of the valley and pread out in broad aprons bordering the valley sides. The tribtaries that enter the Sheyenne from the present quadrangle are ı nearly all cases short, extending seldom more than one to two iiles from the main valley. Their sides and bottoms are, howver, generally steep and the material removed is that distributed long the sides of the main valley. These side coulees are often roded into the shale which underlies the drift, but drift has sually fallen upon the slopes of the tributary streams and of the iain valley so that the hillsides have much the appearance of drift ills, and the soils have much the nature of drift soil.

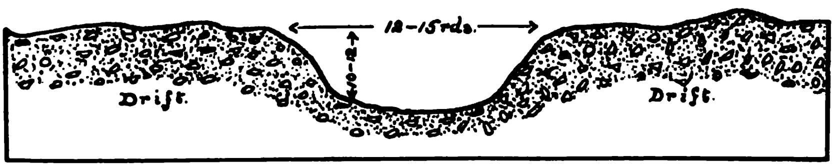
Lake Deposits.—In the southern corner of the quadrangle porons of Casey, Shenford, Sheldon and Highland townships are inluded in the area covered by the water of glacial Lake Agassiz and ıe delta of the Sheyenne river. This delta has been described lsewhere and need be referred to here only in reference to the haracter of the soil upon it. The delta, being a deposit from the lacial Sheyenne river, is composed in considerable part of drift iaterials assorted and arranged by the waters of the lake. The oil of this portion of the quadrangle is therefore loose in texture nd in places is of sufficiently sandy character to be blown by ıe wind into dunes. Only a small portion of the silt covered lain of Lake Agassiz falls within the area of this quadrangle, in ldred and Highland townships.

Soil Deposits From Shale.—In Oakville township the shale is not covered with any perceptible mantle of drift. The soil here is that formed from the disintegration of the shale. It is a compact and clayey soil and is subject to cracking into prismatic blocks during the dry season of summer. This type of soil is very similar to that locally known in the Red river valley as "gumbo," and classified by the U. S. Department of Agriculture as Fargo clay, and is the source from which the Fargo clay was originally derived.



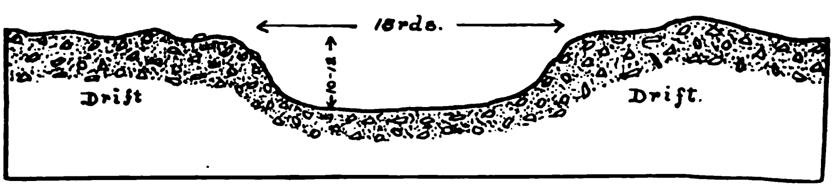
(a) SECTION OF GLACIAL CHANNEL (BRANCH OF MAPLE).

Section 32, Binghampton township. Bottom of valley is a hay meadow; no modern stream channel; sand and gravel exposed in sides; gravel probably under the soil of the bottom. (See pp. 51, 52.)



(b) SECTION OF GLACIAL CHANNEL (BRANCH OF MAPLE).

Section 34, Weimer township. Gravelly banks; no modern stream channel; a little water in pools. (See pp. 37, 51-54.)



(c) SECTION OF GLACIAL CHANNEL (BRANCH OF MAPLE).

Section 36, Oriska township. Channel eroded in drift; no modern stream; a little water stands in pools.

THE HISTORY OF MAPLE RIVER.

By Daniel E. Willard.

(By permission of the U. S. Geological Survey.)

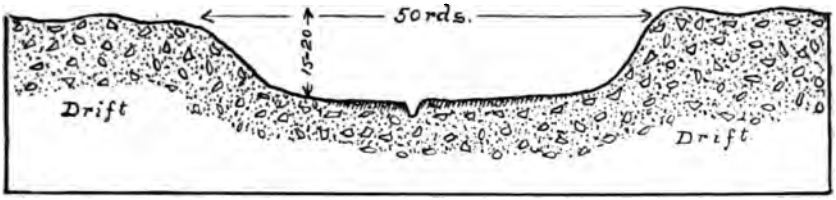
The history of the Maple river is closely associated with the progress of recession of the ice of the great ice sheet. A tract extending across the central portion of the quadrangle in a generally north-south direction, embracing approximately the townships in range 56 west, is non-morainic except for occasional hills and small morainic areas. The deposit formed at the next halting place of the ice to the eastward may be referred to for convenience as the Buttzville moraine. At the time of the formation of this moraine the edge of the ice extended in a generally north by northwest direction to the vicinity of Fingal. It is not thought, however, that the edge of the ice was anything nearly as uniform as would be suggested by a line drawn even sinuously from Buttzville to Fingal and northward. It seems more likely that the ice border was characterized by much irregularity, and that local lobes and re-entrant embayments were many. The facts as observed in the field are more satisfactorily explained on the supposition that the ice edge was irregular and that the recession was slow and that local re-advances probably occurred. When the edge of the ice was at Buttzville it probably was as far west as Fingal, the morainic or strongly rolling hills in Raritan township being correlated in time with the moraines north of Fingal in Binghampton and Springvale townships, and with those north and west of Oriska. The existence of a channel having a broad gravelly bottom, with gravel exposed on its banks, taking its origin north and west of Fingal and having its course to the southeast along the edge of the ice to the southwest corner of Pontiac township, where it entered the channel of the modern south branch of the Maple, indicates a source of water supply as far west as Fingal, and would suggest that the ice still covered the territory west of Tower City and Enderlin. In section 26, Raritan, a channel from the west joins the Fingal branch. This channel takes its origin five or six

miles west in Thordenskjold township, and indicates that it was formed by water from the ice sheet in this region. Embracing an earlier time and before the ice had uncovered the region later occupied by the Fingal channel the waters seem to have escaped by a southeasterly course from section 27, Raritan, entering the channel of the South Branch in section 14, Moore township.

The well defined channel of the small intermittent tributary of the Maple which springs from eastern Thordenskjold township and joins the channel referred to in section 26, Raritan, which is a channel only, containing no water except in standing pools during the season of melting snows and heavy rains, was the earliest channel of the Maple system to be formed.

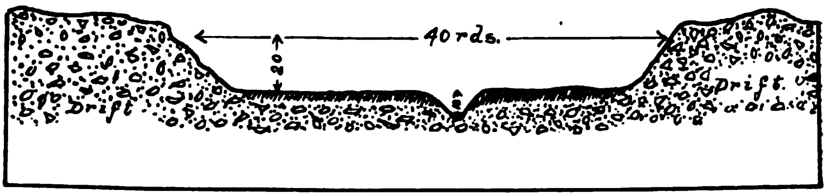
The south branch of the Maple, which enters the main valley at Enderlin, is an interesting example of a reversed waterway. As will be shown below, this channel was the avenue of escape to the Sheyenne for the waters from the retreating ice edge from the whole central region of the present quadrangle, and also from far north of Buffalo and Tower City beyond the present quadrangle. The channel is clearly defined, having steep sides thirty to forty feet high in northeast Moore township, and from fifteen to thirty feet in southern Moore and Fuller township. Very little water passes through the channel now except during the spring season. In fact throughout much of its course the channel bottom is a fine level hay meadow. Gravel shoulders occur along its course. The channel is continuous from Enderlin west and south to section 20, Fuller township, where it enters the Sheyenne valley about one mile south of the boundary of the present quadrangle, by a hanging valley about seventy-five feet above the present Sheyenne river. The present drainage into the Sheyenne river from this channel is from hardly more than a mile or two from the Sheyenne valley, though the divide is so indefinite as to be undeterminable except by leveling. The modern discharge through this channel is therefore almost wholly toward the north into the Maple.

The earliest Maple river, therefore, was a glacial stream emerging from the ice border in eastern Thordenksjold township, and having a southeasterly course to section 14, Moore township, and thence south by southwest to the Sheyenne river. This was soon reinforced by the Fingal branch, the two uniting in section 26, Raritan, and flowing near to the ice border to three miles west of the present city of Enderlin, thence turning southward to the channel of the South Branch and the Sheyenne.



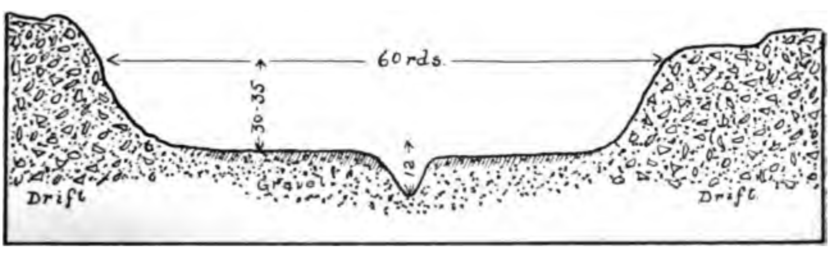
(a) SECTION OF GLACIAL CHANNEL (MAPLE RIVER VALLEY).

Section 11, Tower township. Very small modern channel with a little water standing in pools; bottom of valley a hay meadow. (See pp. 51-54.)



(b) SECTION OF GLACIAL CHANNEL (MAPLE RIVER VALLEY).

Section 10, Clinton township. Modern stream channel 10 feet deep, dividing the old floodplain into terraces; old floodplain 20 feet below general prairie level.



(c) SECTION OF GLACIAL CHANNEL (MAPLE RIVER VALLEY).

Section 33, Clinton township. Hay meadow on bottom underlain by 18 feet of gravel and sand; several old channels on the flood plain; rolling topography of prairie along the sides of the valley shows that there is no relation between the prairie and the valley.

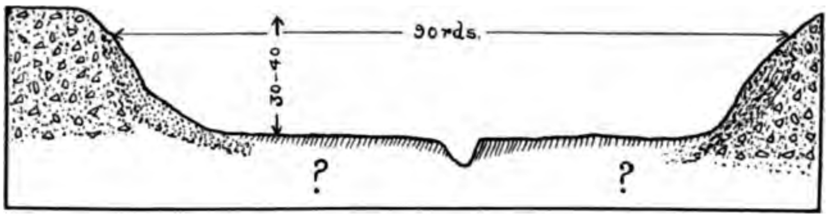
A further recession of the ice permitted the formation of a channel in eastern Binghampton which carried the waters south and east to the present channel of the main stream, but the waters were deflected westward in section 28, Pontiac, by the barrier of ice, and were conducted to the Sheyenne by the channel of the South Branch. At this time the edge of the ice probably lay over the present site of the city of Enderlin, and the morainic knobs and rounded hills in western Clinton were probably being formed. It seems likely also that the knobs west of Tower City were also formed in the marginal portion of the ice sheet at this time.

The next recession of the ice border uncovered the region of the upper course of the main channel of the Maple river, and as far south as Enderlin. The halting place of the ice is probably represented by the hills in eastern Casey and Liberty townships, the morainic and rolling hills in the region of the Alice lakes in eastern Pontiac and Clinton townships, and the round knobs in western Tower and Cornell townships. This recession of the ice freed the whole region of the upper Maple, except the more easttern branch of the upper portion in Tower and Cornell townships, which extends east of the group of hills in western Tower and Cornell townships, referred tò as probably representing the place of the ice border. The morainic and rolling topography in the northeastern corner of the quadrangle has a north-by-northwest trend in the alignment of the hills and ridges, which is taken to indicate that the region of the eastern branch of the main Maple channel had not been yet uncovered, the northeastern corner of the present area being the last to be freed from the burden of ice.

The main channel of the Maple from the vicinity of Tower City and southward to Enderlin, together with the western branches—and it will be observed that all the branches of the Maple enter it from the west--was now being eroded. The ice sheet still formed a dam just east of the present site of Enderlin, and the waters were compelled to turn westward away from the ice wall, whence the waters were conveyed by the present course of the South Branch to the Sheyenne.

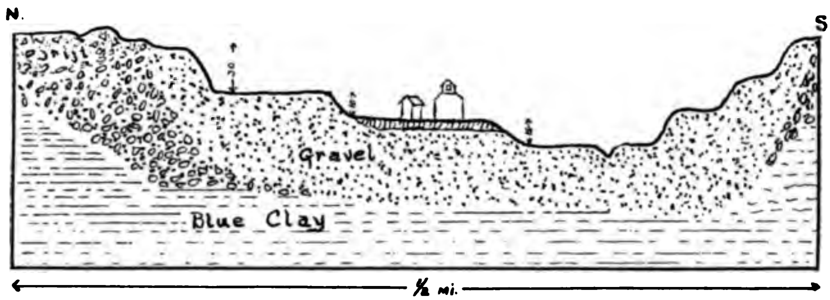
It was not until another recession of the ice border had occurred and the valley which subsequently became the place of glacial Lake Agassiz had begun to be relieved of its burden of ice that the Maple finally became free to discharge its waters eastward by the present course into glacial Lake Agassiz in section 32, High-

land, and the great channel which had long been supplying water to the Sheyenne, which had been the avenue of escape for the ice waters brought away from the ice border during as many as four stages of recession, and had been a part of the trunk line of the Maple during these four periods, from this time ceased to be a part of the main channel, and became what it now is, a channel of reversed drainage occupied by the small intermittent modern South Branch. It was not therefore till the ice had melted off from the entire quadrangle, with the exception of the northeast corner, that the full Maple system became established in its present course. By this time glacial Lake Agassiz had begun to be formed by the enlargement of the Sheyenne river, the waters of the latter being discharged between the wall of the retreating ice sheet on the east and the higher land to the west, ten miles south of the southeast corner of the present quadrangle.



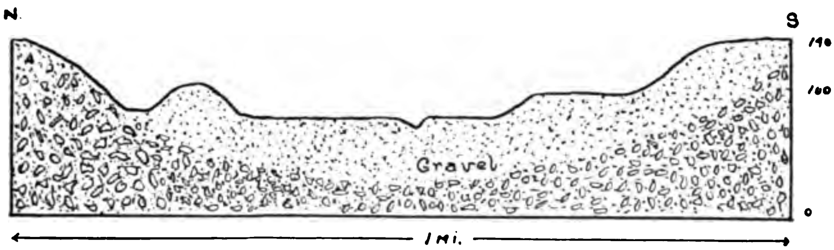
(a) SECTION OF GLACIAL CHANNEL (SOUTH BRANCH OF MAPLE).

Section 27, Moore township. Valley bottom 90 rods in width; hay meadow on bottom; sides 30 to 40 feet high, with very small modern stream channel; no water except in pools. (See pp. 36, 37, 51, 52, 53, also Plate XIV a.)



(b) SECTION OF GLACIAL CHANNEL (MAPLE RIVER VALLEY).

City of Enderlin, section 4, Liberty township. Showing terraces. and gravel underlying valley.



(c) SECTION OF GLACIAL CHANNEL (MAPLE RIVER VALLEY).

Sections 2 and 3, Liberty township. One mile east (below) city of Enderlin.

A PECULIAR TYPE OF HILLS.

By Daniel E. Willard and H. V. Hibbard.

:lass of hills differing from terminal morainic hills or ground nic swells is typically developed in the vicinity of Tower City. hills are known as kames, and are considered to have been d by deposition from the slowly retreating ice sheet. Such nay often be appropriately characterized as knobs. Not in- ently they stand alone, surrounded by a broad expanse of level prairie. Wherever they have been seen in section they been found to have been made of sand and gravel largely, :requently more or less of clay, irregularly but definitely strat- A number of such hills are nearly round, but frequently they somewhat elongated. No trend that could be called general be observed, though in several instances in Buffalo, Tower)riska townships the longer axes are in a generally northwest outheast direction. In outline these hills are usually smooth ounded giving a subdued and softened aspect to the surface, npared with the more rugged terminal moraine hills. Lakes ot associated with hills of this type, as is the case with hills terminal morainic type. Hills of the type described occur ne extent associated with morainic hills in the less ruggedly nic portions of the quadrangle, but the more striking examples olated, or in groups apart from terminal moraines.

most conspicuous and typical hills of this character occur a radius of five miles of Tower City. This is the portion of adrangle most free from terminal moraines. The region be- Buffalo and Oriska is a vast level plain marked by three :ls of the Maple system, the view across the flat expanse interrupted only by these knob-like hills.

se have been interpreted as representing recessional deposits, ılations from the melting ice sheet formed in re-entrant in the ice border, in holes or basins melted in the stagnant :et, or formed beneath the ice sheet from materials borne le ice by the water descending from higher levels either upon or subglacial streams.

SOIL SURVEY OF THE CANDO AREA.

By Elmer O. Fippin and James L. Burgess.

(By permission of the Bureau of Soils, Department of Agriculture, Washington, D. C.)

LOCATION AND BOUNDARIES OF THE AREA.

Towner county is located in the northeastern quarter of the state, and is bounded on the north by the Canadian line. The greatest dimension of the county is from north to south, measuring forty-three and one-half miles, or a little more than seven tiers of townships, while its width from east to west is twenty-four miles, covering four townships. The area surveyed comprises the two southern tiers of townships and has an extent of 288 square miles, being twenty-four miles east and west by twelve miles north and south.

The main line of the Great Northern Railway crosses the state about eight miles south of the county, and from Churchs Ferry a branch line extends in a northerly direction through the center of the area surveyed to the town of St. John, near the Canadian line, in Rolette county. Cando and Maza are the only shipping points in the area. Cando is a town of approximately 2,000 population, contains a number of substantial business houses engaged in handling the various supplies and products of the region, and is the site of large elevators belonging to six different companies. Maza is a small village, being important chiefly as a grain-shipping center.

In the prosecution of the field work of the survey the bureau had the co-operation of the state agricultural and economic geological survey, to the extent of furnishing two men and paying their expenses for a period of nearly a month and a half.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The area, like all of the surrounding region, is a comparatively new one agriculturally. It was first opened for settlement in 1883, and under the homestead and other similar federal enactments, such as the tree-claim and pre-emption acts, all of the land has been taken up. No land was sold by the government or granted to trans-

MAP SHOWING GREAT ICE SHEET OF NORTH AMERICA.

(Referred to on p. 30 as figure 8.)

portation companies. Upon the organization of the state in 1889 sections 16 and 36 of each township were given to the state for the purpose of creating a school fund from the moneys derived from the sale of such land, which is disposed of at public auction at a price not less than $10 per acre. Within eight or ten miles of Cando and Maza all the land had been taken up under the above provisions at least fifteen years ago, and in the area as a whole no land has been open for homesteading for five or six years. A little more than half the allotted school land remains in the possession of the state, and is the only "public land" available.

During the first six years settlement was rapid and most of the land was filed upon, the title being "proved" to a considerable part; but in the three years beginning with 1888 the crops were almost a complete failure because of weather conditions, and the loss fell so heavily on a large number of settlers that a great many of them were forced to abandon their land, which either reverted to the government or went to persons holding it as security for loans. Indeed, it is said that at one time following the third failure, in 1890, the exodus was so great that it looked as if the region would be almost depopulated. Under these conditions a few of those who remained and were able to do so acquired much of this abandoned land by purchase at a very low figure. Quarter sections of land sold for $200 and $300, or even less, because, first, there was plenty of land in the vicinity to be acquired by simple residence; and, second, because most of the persons who had lent money on the land were willing, in the face of financial conditions then prevailing, to accept whatever could be realized from an immediate sale. Large areas of land that now form some of the largest farms were acquired in this manner.

It is said to be a peculiarity of this region that about every third or fourth year since settlement began a large crop has been obtained, while in the intervening years crops have been either only moderate or an actual failure. The year 1891 gave an immense crop, helping those still remaining in the region to retrieve their previous losses, and since that date there has been no repetition of the almost absolute failures of earlier years. In the following prosperous years active settlement was renewed and has continued to this time. Since the early nineties the price of land has been steadily advancing, this being especially true since 1898: Prices now range from $10 up to $35 an acre, depending on the char-

acter and condition of the soil and the location of the land with reference to the two towns and the railroad.

The population of the area has been drawn from many states and also from foreign countries. Men from New England and Illinois have settled here, and there are many of Norwegian parentage. Some of the latter, however, are Americans by birth and have come from Wisconsin and Minnesota.

From the very first spring wheat has been the staple money crop, to which all others are subsidiary. Barley, oats and flax were early introduced to assist in getting the native prairie in good condition for growing wheat, the first two furnishing feed for horses and other stock; but in 1898 the relative prices of wheat and flax were such that on many farms flax was given the preference, and continued to increase in favor until about 1901 or 1902. Since that time the fluctuation in the price of both grains has restored the prestige of wheat, though flax is still grown in considerable quantities as one step in the rotation of crops. Flax and barley have long been considered very satisfactory as the first crop on new land, following which wheat succeeds better than if planted on virgin soil. The flax has always been grown for seed only. Within the past few years macaroni wheat has been introduced into the area and is increasing in favor among the farmers, several hundred acres of it being grown at present. The grain emmer, known here under the name of "spelt," has also been introduced. Both of these grains have been introduced at the instance of the bureau of plant industry.

In considering the agricultural development of the region, the advent of the railroad in 1888 must be regarded as a highly important factor.

The changes in the methods practiced have been chiefly those that accompany the transition from the pioneer condition to the more intelligent system of the progressive, well-to-do farmer, who keeps pace with the improvements along agricultural lines. One change that may be noted in this connection, however, is the different treatment now given to new land, which was at first plowed shallow and the following spring "backset," or replowed after the sod had partially rotted. The land so managed was prepared and planted the same season. Later the "backsetting" was omitted, and a practice now in vogue is to plow and prepare new land in the spring and seed it to a crop like flax. The success of the lat-

FLOWING WELL, CITY OF ENDERLIN.

ter method is more dependent than the other on the moisture conditions of the current year, the yields being larger in wet seasons.

Some inquiry was made to determine whether there had been any appreciable reduction in crop yields on the lands longest in cultivation. The replies were varied, indicating that if there has been any decrease in yield it is so small as to be scarcely noticeable.

CLIMATE.

This area, with an average precipitation of nearly twenty inches, belongs to the semiarid division of the country, but there are certain modifying factors which almost place it in the humid division. An examination of the appended table, compiled from weather bureau records, will show that about 75 per cent of the rainfall occurs in the warmer months, from April to October, inclusive. These figures are normals for a series of years, and there are wide fluctuations from year to year, unusually dry seasons alternating with seasons in which the rainfall is sufficient to class the region with the humid country farther east. On the whole, the problem of a sufficient moisture supply is the most important one in the region, and the one that most largely determines the crop returns under the methods practiced. In the season of 1904, however, an excess, and not a deficiency, of rain caused much injury.

Frosts always occur early in September, and between the 1st and the 15th of November permanent low temperatures begin to prevail, the ground freezing and remaining so until the following spring. The humidity in winter is low, and consequently the low temperatures are not so severe on animal life as the figures would seem to indicate. Snow generally covers the ground to a depth of several feet throughout the winter, but the total amount of water that falls in this form, as shown by the tables, is only a fraction of an inch during each of the coldest four months. The ground freezes to a depth of from five to eight feet.

About the 1st of April the soil begins to thaw, and usually from the 10th to the 20th of the month plowing and cultivation are possible, even though the soil be frozen below. By the 1st of May, or even earlier in some years, the surface soil is warm enough to germinate seed.

In this region a given amount of water is more effective in causing crop growth than in warmer sections, because the surface evaporation is less. As is indicated by the temperature of the ground

water near the surface in wells and other places, the lower subsoil never becomes very warm. All processes of oxidation and decomposition are correspondingly slow, and this fact, coupled with the additional one that the seasons are comparatively short, probably explains why all the soils are so rich in humus or partly decomposed organic remains. There is a comparatively small amount of leaching.

In winter the temperature sometimes falls to forty degrees below zero, and the general conditions are very severe on animal life. In summer hailstorms sometimes do great damage to crops if they happen to be in a nearly ripe condition. These storms, however, are never of general occurrence, and usually cover narrow strips from a fraction of a mile to several miles in width.

There is a free and unobstructed movement of the winds, which occasionally attain high velocities, but the damage to crops from this cause is not great, as in some parts of the west.

Normal monthly and annual temperature and precipitation.

Month	Churchs Ferry		Dunseith	
	Temperature	Precipitation	Temperature	Precipitation
	Deg. F.	*Inches*	*Deg. F.*	*Inches*
January	2	0.63	5	0.10
February	3	.51	1	.30
March	16	.96	14	.65
April	40	2.38	40	1.00
May	53	2.02	54	.90
June	63	3.98	64	3.58
July	68	2.40	68	2.51
August	65	1.84	64	1.85
September	55	1.40		
October	41	1.71		
November	17	.87	25	.40
December	9	.50	8	10
Year	36	19.20		

PHYSIOGRAPHY AND GEOLOGY.

In surface features the Cando area is an undulating, treeless prairie, a little rougher near the borders than in the central—particularly the east-central—part. The area is also slightly trough-shaped, with the lowest portion forming a broad, shallow valley that crosses the survey a few miles east of the center. The elevation varies from about 1,475 feet to nearly 1,600 feet, and the general slope is southward. The topography consists of low elevations, the great majority of which have a general northerly and southerly trend. All of the elevations have gentle, gracefully rounded slopes. The topography, however, is not of the dissected

(a) A GLACIAL CHANNEL, VALLEY OF SOUTH BRANCH OF MAPLE RI

Section 20, Fuller township. (See pp. 36, 52.)

(b) A KAME, ONE MILE WEST OF SHELDON.

type, and bears scarcely any relation to stream-erosion forms, but has been produced by entirely different factors, to be discussed a little further on. Three miles north of Cando, and in a few other places, the surface is made up of knolls and kettlelike depressions, some of which contain small lakes.

The drainage system of the region is unique in several respects. The rather extensive system of streams and drainage lines has not been developed by the present rainfall, and consequently they are not actively eroding their channels. Many of the streams, or coulees, as they are called in this section of the country, are quite large, and their meandering course indicates that at the time they were developed the fall was not great and the water moved rather slowly. The main stream is the Big Coulee, which crosses the area a few miles east of Cando. With the exception of a small extent of country in the extreme southwestern part, the drainage of which flows into the Hurricane lake system, the drainage water of the area finds its way into the Big Coulee, either in the county or at some distance to the southward. All of the channels are much clogged by a growth of water-loving plants. At intervals many of the streams pass through broad swales or swampy depressions, from an acre or two to many acres in area, over which the water spreads, while throughout the extent of the survey are numerous shallow depressions of about the same size with no outlets that contain from a few inches to a foot or two of water during most of the year. In the eastern half of this area, aside from the southeastern corner, many of these swamps have the appearance of having been part of a main line of drainage, and are traversed by a distinct channel. In addition, along all of the coulees are many abandoned channels of ox-bow form that have been sufficiently filled to make cultivation possible. The most notable examples of this occur along the Big Coulee northeast of Cando. The former meaderning of this stream over a wide territory is here very evident.

In the course of the survey it seemed advisable to indicate on the map numerous lines along which the drainage water collects, and along which, at some earlier time, it was probably drained, and this has been done by means of broken lines. At present these are indicated by poorly drained areas of soil, with discontinuous wet-weather swamps, too small to be shown in the usual way, yet having considerable influence on the agricultural value of the land they traverse.

A further peculiarity is the way in which the various coulees are connected by these lines of drainage, and also the parallel position and near approach of several of the systems to each other. A study of the accompanying map will show two large coulees coming down from the north, one on each side of the Big Coulee, which they gradually approach and into which they finally empty. These, in turn, are formed by the union of streams, which continue parallel and near to each other for distances of several miles.

The surface geology of the area and of all the surrounding country is of the glacial type. The Dakota lobe of the ice pushed down over this country, forming a continuous mantle of glacial till, and during its recession and temporary advances formed lines of gravelly hills called terminal moraines. Associated with these is the roughest topography of the area, in which are found the small glacial lakes.

The melting of the ice during the period of recession produced large volumes of water that drained off to the south, and it was this water derived from the glacier in the immediate vicinity and from regions many miles to the north, beyond the Turtle Mountains, that produced the system of coulees mentioned above. In The Story of the Prairies, Professor Willard describes the Big Coulee as forming an outlet from large bodies of glacial water far to the northward into Devils Lake and thence into the Red river valley. The passage of this large volume of water through the area, as floods laden with sediment, and with varying currents, is responsible for the deposit of the large masses of material giving rise to the soils of the area, other than those formed directly from the boulder clay. The various grades of sand and gravel, mostly stratified in the form of bars and ridges, and of the huge mass of silty clay in the vicinity of Cando, were probably formed by this agency of the glacial waters. All of the surface forms are the result, directly or indirectly, of the action of ice, and the depth of the glacial material ranges in different parts of the area from thirty or forty feet to more than 100 feet.

SOILS.

The most prominent characteristic of the soils of this area is the large amount of organic matter and lime they contain, as compared with soils of similar texture farther east and south.

The preponderance of organic matter is not due to a large original amount produced in the soil, but, as was intimated in the discussion of climate, it is a result of the meteorological conditions. The source of all the humus is the plant roots and stems that were left in the soil from season to season by the prairie grass before cultivation began and by the cultivated crops now. All processes of decomposition are hastened by a high temperature, and the longer it continues the more thorough they will be. In this region the summers are comparatively short, the atmospheric temperature is not high on the average, and the soil temperature is comparatively low. This condition hinders the bacterial and fungus growths that are essential to rapid decomposition of organic matter, and a gradual accumulation of humus is the result.

The amount of humus present is the cause of the dark color of the soil of the area—a color that tends to increase the amount of heat absorbed during sunshine, thus maintaining a higher soil temperature. This is an important fact when associated with areas having as short growing seasons as here, and it is probable that the crop adaptation of the region would be quite different if the soils were a very light color, even though they contained the same amount of plant food as at present.

A large amount of limit is distributed through all types of soil, but is most abundant in the loams and gravelly loams. It has been derived from the grinding up by the glacier of lime-bearing crystalline rocks and also of considerable amount of limestone. This has been subsequently redistributed and in some places concentrated through the agency of the soil water. The largest accumulations are between the twelfth and thirtieth inches, where lime sometimes appears to form more than a third of the bulk of the soil. In gravel beds covered to a depth of from fifteen to thirty inches by silty material all of the pebbles in the upper part of the gravel are covered with lime, or the whole mass may be cemented together by depositions from the water leached from the soil above.

This large amount of lime is very useful in the soil, since it tends to increase the granulations of the fine-textured types, prevents acidity from the decomposition of the organic matter, which process it hastens, and is favorable to the growth of the grains most abundantly produced in the region. For the growth of flax, however, less lime is desirable.

Five types of soil have been recognized, the names and extent of which follow:

Areas of different soils.

Soil	Acres	Per cent.
Marshall loam	79,936	44.2
Clyde loam	70,016	38.7
Clyde clay	18,880	10.4
Clyde fine sandy loam	10,880	6.0
Marshall gravel	1,344	.7
Total	181,056	

All of the types appear very silty in the field, and, except on the lightest sand and gravel points, which are very small in extent, there is considerable similarity in the first ten inches of soil throughout the area.

CLYDE LOAM.

The soil of the Clyde loam is a black silt loam or loam, with an average depth of twelve inches, but with a range of from ten to twenty-four inches. The greater depth is found in the lowest positions adjacent to the coulees. The subsoil is a light-colored silt clay loam, or clay, the upper part, when dry, being a pale yellow to gray, and the color changing to a darker yellow with increased depth. The type has little material coarser than the finer grades of sand.

The Clyde loam is distributed throughout the area, but the largest body is in the eastern half, where it is the predominating type, and occupies a sort of broad, flat basin, about ten miles in width, cut at intervals by areas of other types. Toward the eastern boundary of the area and throughout the western half it is the type of second importance in extent, in the latter location forming elongated bodies of variable size surrounded by the Marshall loam.

The surface in general is nearly level or only slightly undulating, while in detail it is appreciably uneven in a number of places, due to shallow channels and saucer-shaped depressions. The large area first mentioned lies at an elevation halfway between the highest knolls and the lowest depression, and in other parts it fills many of the troughs in the surface of the Marshall loam. The shallow depressions mentioned are rather numerous throughout the type, but most of them are of very small extent—less than two acres. Where they are of considerable size they have been mapped as a

distinct type, because the drainage conditions are such that the soil has been much modified.

The natural drainage of the type is not perfect, and in a region of greater rainfall the condition would be serious; but with the usually light precipitation of this section little trouble is experienced from excess of water, and then only in the wettest seasons and over a comparatively small proportion of the type. Most of the coulees are bordered by the Clyde loam, and it surrounds most of the swampy areas mapped as Clyde clay. Near these in wet seasons the crops may be damaged. In addition, there are lines along which, when there is an excess of moisture, the water tends to accumulate, forming a series of wet-weather ponds a few rods in extent. The most prominent of these lines of drainage have been indicated on the map by broken blue lines. In average seasons all such places may be readily cultivated, and give the largest yields, although there is loss of crops in a wet season. Much of the land could be drained by constructing open or tile drains emptying into the adjacent coulees. Remote from outlets, however, it would not be practicable to put in a drainage system for small areas that are injured only about every fourth season.

Some minor variations from the typical soil material, and other peculiarities in texture that are best described at this point, are: The more coarse and mealy character of the soil in the immediate vicinity north and east of Cando; the noticeably fine sand content of the soil for some distance out from the borders of the bodies of the Clyde fine sandy loam, especially north and east of Cando; the heavier and somewhat clayey subsoil in the lowest places where the drainage is defective, and the slightly heavier character of the type, as compared with the large eastern area, in the small bodies surrounded by the Marshall loam.

The origin of the Clyde loam is not well understood, but it is thought to be the result of the accumulation of material in the lower levels by the drainage water. Since the volume of this drainage is insignificant at present, the material must have been deposited at some earlier time, presumably during the period when the drainage of the retreating glacier passed through the area. In the vicinity of Cando the depth of this material is ten feet or more. The character of the surface and the relation of the material to the coulees, as well as to the numerous abandoned channels, which are very prominent along the Big Coulee, northeast of Cando,

would seem to indicate the deposition of the material by shallow, slow-moving flood waters. There is no important variation between the material forming the type on the highest levels and that on the coulee bank. The soil is usually a little deeper next to the coulee, but the subsoil is of the same light-colored, clayey character. An example of this occurs along the coulee northeast of Maza, through several sections ,and includes several hundred acres, where the black soil is several feet deep next to the channel, and gradually shallows toward the highest level.

The type may be regarded as a secondary material derived originally from the glacial till, but that it is distinct from the boulder clay is evident.

A large quantity of lime is distributed throughout this soil and is often apparent from the color of the material. The accumulation is largest in the upper part of the subsoil. There is also present a large amount of gypsum ($CaSO_4$), mostly in a crystalline form. It occurs as a granular material in small pockets and seams through the section of the subsoil.

In general, the alkali salts are not sufficiently abundant to be injurious to crops, but there is a slight excess in some instances that is more fully treated under "alkali soils." It is found in the lowest places, where the drainage is most defective, and is most concentrated in the lower part of the soil section.

All the crops of the region, including wheat, barley, oats, flax and potatoes, are grown on the Clyde loam with good results. In its natural condition it has the highest productive power of any of the soils. In the best seasons wheat will yield from thirty to thirty-five bushels, barley forty to forty-five, oats forty-five to sixty bushels and flax from eighteen to twenty-three bushels per acre. Not enough corn is grown to determine what the yielld would be. Potatoes make 200 bushels or more. These yields represent the maximum returns in favorable seasons, and are the only true guide to the productive power of the soil. In other seasons a great variety of yields is obtained, depending on the amount of rainfall and the management of the land. It is in fact the best soil in the area for the staple crops of the region, and is also well adapted to the production of potatoes. The same soil farther south would be an ideal one for corn growing. In this latitude, however, a lighter type of soil is better suited to corn. A variety of forage crops and grasses suited to the climate may also be grown success-

fully. The smooth brome grass thrives on this type. In the best-drained positions potatoes may be made to yield very well, the tubers being of the finest kind. A variety of garden vegetables is also grown, and some excellent small fruits, such as currants and gooseberries, are produced.

In its relation to moisture the type is very satisfactory. It is readily cultivated into a friable loam that takes up water quickly and conducts it into the subsoil, which has a large water-holding capacity. With proper cultivation to conserve moisture, the most protracted droughts of the region may be withstood and fair crops obtained.

The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

Mechanical analyses of Clyde loam.

No.	Locality	Description	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
11646	SE. ¼ sec. 17, Maza Tp.	Black loam, 0 to 12 inches	0	4.9	3.9	15.7	15.8	42.4	16.2
11644	Cen. sec. 26, E. half Badger Tp.	Black silty loam, 0 to 12 inches	[illegible]	1.1	1.5	9.9	11.2	55.7	19.5
11648	SE. ¼ sec. 20, W. half Badger Tp.	Dark loam, 0 to 12 inches	.8	2.6	3.0	8.8	11.0	48.9	24.6
11649	Subsoil of 11648	Clay loam, 12 to 36 inches		5.3	4.1	10.1	9.8	34.8	34.1
11645	Subsoil of 11644	Clay, 12 to 36 inches	.0	.3	.5	5.2	4.8	47.6	41.5
11647	Subsoil of 11646	Clay, 12 to 36 inches		3.3	2.1	4.3	5.7	38.2	45.0

The following samples contain more than one-half of 1 per cent calcium carbonate ($CaCO_3$): No. 11645, 17.8 per cent; No. 11646, 3.2 per cent; No. 11647, 17.4 per cent; No. 11649, 13.8 per cent.

MARSHALL LOAM.

The soil of the Marshall loam is a loam or heavy sandy loam of very dark or black color, containing a small percentage of fine gravel. It is not a very uniform soil, and there are many small, low knolls, from a few feet to several rods in extent, where the material is very gravelly, while in intervening areas the texture is more silty. At from one to two feet below the surface there generally, but not always, occurs a thin stratum a few inches thick consisting largely of coarse sand and gravel, while from twelve

to twenty inches the material is of a light, often gray color, which is due chiefly to the presence of a large amount of lime carbonate, in extreme instances forming from a third to a half of the bulk of the soil.

The subsoil below the gravelly stratum is a stiff, gritty material, sticky and pasty when wet. The color is a light gray, which changes to a yellow with increased depth. The angular fragments of sand and fine gravel may make up a considerable part of the mass and are mixed uniformly through it. When this gritty material becomes dry it bakes and becomes very hard and resistant.

The Marshall loam is the predominating type of soil in the western as the Clyde loam is in the eastern half of the area. Its surface is very gently rolling or undulating, but not to an extent to interfere with cultivation. The surface is made up of low, rounded knolls and ridges, a large majority of which have a northerly and southerly trend. On some of the higher points are found small beds of gravel that would be classed with the Marshall gravel if they were of sufficient extent. In sections 7 and 18 of Maza township, on top of a high ridge at that point, these gravel and sand pockets are rather numerous, and associated with them are many large boulders. These boulders range from a few inches to several feet in diameter, and boulders of the same character are of common occurrence throughout the type. They are angular and subangular in shape, and composed of a variety of minerals. Various kinds of granites are common.

Kettle holes are of frequent occurrence. Many of the depressions between the ridges and knolls are poorly drained and often swampy. This gives rise to the many areas of the Clyde clay associated with this type, which will be noticed on the map, particularly on the eastern margin and in the west-central part. Their presence is a considerable hindrance to cultivation in some places, because they cut the surface into irregular areas.

With the exception of the lowest parts of the depressions between the ridges the drainage is good, and even in the areas excepted, if they are of considerable extent they are shown as a different type. The Marshall loam, as a rule, forms the most elevated part of the area and has a moderately sloping surface and the excess of water readily drains away, while the soil itself being of a porous character, the water that falls upon it is rapidly absorbed. The subsoil, however, is more dense and impervious and absorbs

water slowly. The twenty inches or more of porous material on the top has a decided power to retain moisture, and keeping it in contact with the subsoil for long periods the latter gradually becomes moistened. Thus a large amount of moisture may be stored and, by proper cultivation, retained until such time as it is needed. Some of the wet areas may be easily and cheaply drained, while for others the process would be too expensive to be practicable under present conditions.

The Marshall loam is formed by the weathering of the true boulder clay which comes to the surface in the areas indicated by the occurrence of the type. With this weathered material have been incorporated considerable quantities of organic material, but at a considerable depth the blue boulder clay is found in its original condition, the difference in color being due, it is believed, to the change in form of the compounds of iron, due to weathering.

This type contains more lime than any of the others, but a comparatively small amount of gypsum, and that in the most silty areas. The lime is most concentrated between the twelfth and the twenty-fourth inches, where it may constitute the greater part of the soil mass. The included pebbles are usually heavily coated with it. The small depressions mentioned are often encircled above the line of saturation by a band several feet in width, in which there is a large accumulation of lime at the surface. On these places flax is invariably a failure, and other crops may be affected.

All of the staple crops of the region are produced on this type, but are less uniform in growth than on the Clyde loam. The crops are best in the wet seasons, but even then a slightly spotted appearance in the fields may be observed. In a dry season this lack of uniform growth is much more noticeable. The coarse stratum, being unequally distributed, checks the proper movement of moisture upward to the plant roots, especially when the upper part of the section has become very dry. The process of movement from one part to the other is very slow, and if the upper soil be quickly dried out the plant will suffer for moisture before the supply is replenished from the lower subsoil. There is, in addition, probably a hindrance to the downward development of the plant roots. With the best management the yields of the grain crops may be made to approach very near to those given for the Clyde loam. Flax, however, does not do quite so well.

The following table gives the mechanical analyses of typical samples of the soil and subsoil of the Marshall loam:

Mechanical analyses of Marshall loam.

No.	Locality	Description	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
11642	SW. ¼ sec. 16, W half Badger Tp.	Gravelly loam, 0 to 12 inches	1.2	4.9	3.2	13.8	18.0	42.4	16.6
11638	NW. ¼ sec. 7, Athens Tp.	Gravelly sandy loam, 0 to 20 inches	7.6	17.9	15.5	15.6	4.6	16.1	22.5
11640	NW. ¼ sec. 17, Coolin Tp.	Black loam, 0 to 18 inches	3.0	4.7	5.7	18.7	17.4	24.1	25.9
11639	Subsoil of 11638	Sandy-clay, 20 to 36 inches	9.2	23.4	15.8	15.0	3.8	11.2	21.8
11641	Subsoil of 11640	Sandy-clay loam, 18 to 36 inches	2.0	6.2	3.7	13.9	17.0	25.2	31.2
11643	Subsoil of 11642	Light colored clay, 12 to 36 inches	2.2	5.2	3.4	10.8	10.0	28.6	39.3

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11638, 11.3 per cent; No. 11639, 20 per cent; No. 11640, 8 per cent; No. 11641, 25.3 per cent; No. 11643, 17.3 per cent.

CLYDE FINE SANDY LOAM

The Clyde fine sandy loam consists of a very dark or black fine sandy loam, twelve inches in depth, beneath which is a pale yellow or gray fine sandy loam or fine sand that extends to a depth of from two and a half to many feet. The sand subsoil is found in areas occurring on the highest knolls. This is the case on the highest elevations in section 1 and the northeast quarter of section 8 in the eastern half of Badger township; and through the center of section 19, in Maza township, the subsoil is in part a very clean sand, near the medium in grade.

This type is confined almost entirely to the eastern half of the area, where it forms several bodies of more than a square mile in extent. It is closely associated with the Clyde loam and Marshall gravel, and occurs most commonly in small bodies surrounded by the former type and around the base of the latter as a graduation type.

The surface of all of the small bodies of the type is in the form of low knolls or ridges with a gently rounded outline. In sections 4, 5 and 6 of Coolin, and section 1 of Maza township it occupies the intervening depressions as well as the elevations. In the com-

paratively large areas north and east of Cando it forms hill considerable height.

Owing to the elevation, the slope of the surface, and the pc character of the material, the drainage is exceptionally good.

The origin of this type, like that of the Clyde loam, is believ be associated with the post-Glacial drainage of the region. frequently underlaid by silt, and often occupies such a position reference to the drainage channels as to suggest its having deposited in part by the flood waters of an earlier time. It is from pebbles and glacial boulders. It is rich enough in lim effervesce freely with acid, although the soil particles do not pear to be flocculated to any great extent. No crystals of gyp were observed in this soil.

All of the staple crops are grown, but the yields are appreci less than on the Clyde loam, and, as a rule, are less than on Marshall loam. In some instances, where the sand formatio not over three feet in depth and grades into silt, the crops ar good in a moist year as on either of the other types. But the n ture-holding power as a general thing is less and the soil is r affected by dry weather. On the average, wheat will yield f twenty to twenty-five bushels in the most favorable seasons, other crops proportionately. Some uniformly good crops of were observed on this type, but the yield of seed is not so l as on some of the types already described. For the productio corn, potatoes and garden vegetables it is the best type in area, because it is a warmer soil, but it can never be made to duce yields of the small grains equal to those of the heavier ty One essential condition to the production of corn and the c crops enumerated is frequent cultivation to conserve moisture.

The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

Mechanical analyses of Clyde fine sandy loam.

No.	Locality	Description	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.
11636	NE. ¼ sec. 6, Coolin Tp.	Fine sandy loam, 0 to 15 inches	0.3	1.4	4.3	36.4	28.1	18.8	10.5
11634	Cen. S. line sec. 2 E. half Badger Tp.	Fine sandy loam, 0 to 12 inches	.2	2.9	5.6	34.2	25.6	19.8	11.5
11637	Subsoil of 11636	Fine sandy loam, 15 to 36 inches	.2	1.0	3.2	35.5	35.7	10.0	14.4
11635	Subsoil of 11634	Fine sandy loam, 12 to 36 inches	.6	4.7	7.7	34.8	22.9	12.8	16.0

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11635, 9.4 per cent; No. 11637, 5.3 per cent.

MARSHALL GRAVEL.

The soil of the Marshall gravel is a dark-brown or black sandy loam, eight or ten inches in depth, and containing a considerable proportion of coarse sand and fine gravel. The subsoil consists of loose coarse sand and gravel, much cross-bedded and several feet in depth.

The type is of small extent, occupying not more than two square miles. It forms narrow, elevated bodies at widely separated points. Two of these are in the southeastern and southwestern quarters of the area, respectively, and a third and the largest is on the northern margin north of Cando.

The Marshall gravel occurs as isolated knolls and ridges, and is found capping the highest elevations in the area. The largest area forms a large hill, the general surface of which is rolling.

The origin of the type is in some way associated with the glacial drainage of the region. The gravel is very angular, and some of the strata consist of nearly pure quartz sand, while others are made up largely of shale fragments, including an occasional large boulder. In the upper part of the beds, immediately beneath the sandy soil, the rock fragments are heavily coated with lime.

The surface soil is too shallow and the soil as a whole too droughty for successful crop production, and although most of it is

n cultivation to the small grains, the yields are small, in dry seasons ·carcely any grain being obtained.

CLYDE CLAY.

The Clyde clay, from eight inches to two or three feet in depth, s a black clayey loam, very rich in organic matter, with surface ccumulations of a few inches of muck in some places. Beneath he dark soil is a very light colored, often nearly white, material hat varies from a heavy pasty clay to a heavy silty clay, in some istances mixed with sand and gravel, although the last is of inrequent occurrence. The subsoil usually found is a rather heavy lay that becomes more silty at a depth of three or four feet. In ome instances the clay is underlaid with sand. Where the heavy lay approaches to within three or four inches of the surface, so at it interferes with cultivation, it is called "gumbo."

The Clyde clay is scattered through the area in bodies from a ew rods up to several hundred acres in extent. It is associated ·ith all of the other types and occupies the lowest levels. It occurs long coulees, in abandoned stream courses, in depressions at higher levations, and in all other places where the natural drainage is ery defective.

The type owes its origin to its low, flat surface, which is often ish-shaped, and the consequent poor drainage. It represents areas ·here the surface water accumulates and where the small amount f fine material carried in suspension has been deposited from ear to year to form the fine clay. In this material, which is covred by water to a depth of several inches during much of an verage season, many water-loving plants—mostly grasses—grow ı great luxuriance, their decaying roots and stems accumulating rom year to year and with the annual addition of sediment forming ie rich black clay loam that covers the bottom of such places.

Most of the type is a virtual swamp during the early part of the eason, and in wet years is covered with water through the whole ummer. On the map this part of the type is designated by swamp ymbols. Other parts that have been formed in the same way, but ver which better drainage has been established, are under cultivaion. The largest of these are in the center of Maza township, and djoining the Big Coulee in the southwest corner of Coolin townhip. The soil of these areas is a heavy black clay, to which the ıame "gumbo" is frequently applied. A large part of this type

may be cheaply drained, but there remain other considerable bodies over which it would be very difficult and expensive to establish drainage, because of the lack of a ready outlet.

Most of the alkali in the area is found in this type. The salts are apparently accumulated in these places through the agency of the drainage waters, and subsequently concentrated by evaporation, which in some seasons is relatively great. Heavy crusts of salt often form on the borders of the saturated soil, and over small areas all vegetation is killed. The water in such depressions is often brackish, and in some places more so than in others. The problem of drainage and cultivation for the correction of alkali soil is discussed under "alkali soils."

Those areas of the Clyde clay with a fair drainage are devoted to the production of grain, and in seasons of moderate rainfall very large yields are obtained. In very wet seasons, like the present one (1904), the crops over a great part of the area are ruined by the excess of water. If properly drained and well cultivated this type will produce larger yields of wheat than any of the other types in the area. Most of the type is at present used for the production of natural grasses, which in the average season furnish nearly all the hay used in the area. If the areas do not become dry the hay can not be cut, as was the case in the season of 1904, but even in this case a large quantity of hay is obtained around the edges of the areas, where in other seasons scarcely anything would be harvested. The fact that so much and so good hay is obtained from these wet places inclines the farmer to retain them in their present condition rather than to put them under cultivation, especially as this would generally entail considerable expense for drainage.

The following table gives mechanical analyses of typical samples of the soil and subsoil of this type:

Mechanical analyses of Clyde clay.

No.	Locality	Description	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
11652	SW. 1/4 sec. 23, E. half Badger Tp.	Loam to clay, 0 to 12 inches	0.0	0.7	0.8	6.3	14.7	43.7	33.7
11654	SE. 1/4 sec. 20, W. half Badger Tp.	Black clay loam, 0 to 20 inches	Tr.	1.4	1.4	6.8	7.1	45.6	37.7
11650	SE. 1/4 sec. 16. Maza Tp.	Black clay, 0 to 12 inches	.4	1.0	1.0	5.3	5.6	42.4	44.3
11653	Subsoil of 11652	Clay and silty clay, 12 to 36 inches	.0	.2	.3	5.9	24.4	32.2	39.9
11655	Subsoil of 11654	Heavy clay, 20 to 36 inches	Tr.	.8	1.0	4.0	6.8	48.3	39.1
11651	Subsoil of 11650	Dark stiff clay, 12 to 36 inches	.0	.8	.8	3.2	4.1	32.0	59.1

The following samples contain more than one-half of 1 per cent calcium carbonate ($CaCO_3$): No. 11651, 7.4 per cent; No. 11652, 1.1 per cent; No. 11653, 3.4 per cent; No. 11654, 1.9 per cent; No. 11655, 1.9 per cent.

ALKALI SOILS.

Except in a few instances, the condition of the soils of the area as regards excess of injurious salts is not serious, and under proper methods of soil management will never affect seriously the productiveness of the soils in this part of the state.

While there is a considerable quantity of alkali through the glacial mantle, and while in a truly arid climate and with careless irrigation the conditions are such as would give cause for alarm, the rainfall is sufficient to prevent any marked accumulation of the salts within the root zone of the soil over by far the greater part of the area, and what accumulation has taken place is confined mainly to localized spots in small depressions, or in somewhat larger areas of poor drainage. The salts found in such places have been leached from the soil of higher lying areas by the rain water, and have been retained there through obstructed drainage.

A few places were observed on the uplands in the vicinity of some of the larger moraines where the alkali was gradually being leached out of the glacial material and brought to the surface lower down, on the gentler portion of the slope, but the most important occurrences of the alkali salts are confined to the poorly drained

areas along the sloughs and coulees and in the vicinity of the lakelets. Among the more important occurrences may be mentioned the lowlands along the Big Coulee and its larger tributaries, a small, irregular area west and northwest of Maza, a tract around Hurricane Lake, and a small area about four and a half miles north of Cando. Other small areas are found in various parts of the eastern half of the survey. As already stated, the alkali in this area nearly always occurs in small spots and patches, which usually mark places of obstructed drainage.

The alkali in this area owes its origin to the grinding down by glacial action of the various silicate rocks that lay in the path of the ice sheet. Innumerable rock fragments are found scattered all over the country, and range in size from small pebbles to boulders weighing many tons. Rocks containing the lime, soda and potash feldspars predominate, while scattered here and there are found many of the more basic igneous rocks, such as diorites, diabases, gabbros, and various members of the peridotite group. It is doubtless true that from the comminution of these basic igneous extensions much of the sulphur, relatively so abundant in the soil in the form of sulphates, is derived.

Most of the salts in the Cando area are in the form of sulphates. Samples from the worst alkali spots when analyzed by the bureau of soils showed that no sodium carbonate was found; neither was any detected by titrations made in the field. The sulphites of calcium, potassium, sodium, magnesium and the bicarbonates of the last three, constitute the principal salts. Some sodium chloride, or common salt, is present, but none of the analyses showed as much as 2½ per cent of the total salt to be sodium chloride, while there was often 85 per cent of the sulphates. Most of these salts are soluble in water, the principal exception being that of calcium sulphate, or gypsum, which is relatively insoluble.

While the soluble salts of this area are distributed throughout the whole mass of the soil, it is interesting to note the total absence of harmful amounts of alkali in the surface of nearly all the well-drained upland soils. This is especially true in the case of the Marshall loam. The Clyde loam usually contains more salt than any other type in the area, except the clay loam along the coulees and sloughs. In all the well-drained areas, where the alkali is at all noticeable the amount always increases with depth. Cultivation, cropping and surface leaching have removed the excess from the surface a few inches. Excessive accumulation has been largely

kept in check by the nature of the crops grown—crops that tend to allow the least possible amount of evaporation during the growing season; by the large amount of humus in the soil, which creates humic acids that tend to neutralize the alkalinity of the soil; by summer fallowing, which inverts the soil and places next to the subsoil any excess of salts that may have accumulated on the surface, and by the spasmodic nature of the rainfall, which occasionally comes as cloudbursts and flushes from the surface the alkalies that have been deposited by evaporation.

Near the coulees and sloughs and in all the poorly drained areas in the survey the distribution of the alkali in the soil is different from its distribution on the higher levels. Here evaporation causes the salts to accumulate on the surface, and many places are seen in these lowlands where plants are either dead or dying.

The accompanying table shows the amount of salt to increase with depth. Borings Nos. 13, 15 and 20 were taken in poorly drained areas where evaporation had deposited considerable salt near the surface.

Table showing distribution of salts in soil as found in Cando area, North Dakota.

No. of boring	Location	Foot					
		First	Second	Third	Fourth	Fifth	Sixth
1	SE. ¼ sec. 36, R. 65 W., Badger Tp.	0.05	0 32	0.46	0.495		
5	NW. ¼ sec. 5 R. 65 W., Coolin Tp...	.225	.145	.115	.055	0.063	0.083
6	Same as No. 5, but a few feet away..	.042	.05				
7	Same as No. 5, but a few rods away..	.04	.05	.06			
11	Sec. 16, Maza Tp....................	.51	.64	.69			
12	NE.¼ sec. 31, R. 65 W., Badger Tp..	.16	.33	.41			
13	NE.¼ sec. 6, Maza Tp., near coulee..	.54	.24	.20			
15	Big salt flat NW. of Maza	.94	.74	.80			
20	SE.¼ sec. 32, Maza Tp...............	.47	.24	.23			
22	NW.¼ sec. 12, R. 65 W. Coolin Tp....	Tr.	.44	.44			
24	SW.¼ sec. 31, R. 65 W., Coolin Tp...	.19	.41	.60			

In the more important alkali areas along the sloughs and coulees surface drainage should be resorted to wherever possible. Underdrainage is usually impracticable, and in most cases unnecessary, because the only requisite is that the salts be kept below the zone of root action, and good surface drainage, with deep and thorough cultivation, accomplishes this result, the crops of the area being for the most part shallow rooted.

AGRICULTURAL METHODS.

The region is devoted almost exclusively to grain production, and of the grains spring wheat is far in the lead in acreage and total

yield. It is the staple money crop. The other crops grown are barley, oats, flax, emmer (speltz), hay, and a very little corn, and some millet. The wheat, flax and part of the barley are marketed, and the remainder of the grains and the hay are fed on the farm. The hay is almost all derived from the swampy places mapped as the Clyde clay. A little smooth brome grass is grown, but its introduction was recent, and it is confined to a number of small areas that are chiefly experimental. It appears to be adapted to the soil and climate, and, as it is both a good hay and pasture grass, the acreage will undoubtedly be greatly increased. It does best on the Clyde loam and fairly well on the Marshall loam.

For wheat, and in fact for any of the grains, as much of the land as possible is plowed immediately after harvest, as owing to the short season there is none too much time in the spring. The depth is from five to seven inches, except in breaking the prairie sod, when only two or three inches of the soil is turned. The fall-plowed land is generally left in the rough condition through the winter, but a few farmers harrow down their land as fast as plowed, and repeat the process as often as time will permit. They claim profitable results from the practice. In the spring the plowed land is worked into condition, and as early as the season will permit—in the latter part of April or in May—the seed is sown. The thoroughness with which the seedbed is prepared varies greatly with different farmers and in different seasons, but it is generally known that the more care and time bestowed in this preliminary work the better the crop returns will be, especially if the season be an unfavorable one. Wheat is seeded first, and the other crops in the order of their importance to the particular farmer. Oats, emmer and flax require a comparatively long season, while barley will mature much more quickly. As a consequence a greater acreage of barley is sown in wet years, when the season has become late for sowing the other grains. It is often sown in sloughs and wet, cold places in the other grain fields, where it alone will be able to mature.

No well-established rotation is practiced, though many farmers have a succession that they prefer and follow as far as the seasonal conditions will permit. On new land barley or flax is the first crop, following which wheat is grown for two or three years. Barley or flax may follow, and in turn be succeeded by oats. After oats neither wheat nor barley appears to do very well, and flax

gives the best results. Where summer fallowing is practiced it should follow oats.

Summer fallowing is practiced to a considerable extent, the land being plowed late in summer, when most of the weeds are in bloom. The two objects that guide this practice are to permit the land to recuperate and to destroy weeds. For the latter purpose frequent harrowing during the season is essential, and this practice also has the advantage of conserving moisture. It is also recognized that a thoroughly cultivated crop like corn or potatoes gives equally as good or better results in the succeeding grain crop as fallowing.

By the best farmers, cultivated, fallowed and new land is sown in wheat, and after fallowing wheat is sometimes grown for two or three seasons in succession. Oats and barley are largely utilized to free lands from weeds by overtopping and smothering them with their leafy growth. Oats and emmer are sometimes sown together for feed. Emmer yields as much as seventy-five bushels per acre, but is very light and chaffy, and in yield of grain does not materially exceed some of the other crops like barley. Some macaroni wheat is sown, and this crop is growing in favor. A careful farmer who has had experience with it estimates that in a dry season macaroni wheat will exceed the common wheat in yield by about one-third. In other seasons the yields are about the same.

Wheat and other grains are cut with binders and thrashed from the shock. The stubble is cut high, and when sufficiently thick is burned, after the shocks have been removed, to kill weeds. Two species of mustard, sunflower, foxtail and a number of other weeds become very troublesome in the grain fields.

Very little corn is grown, and this is frequently injured by early frost, although in some years mature grain is obtained. The principal use of corn is as fodder, but its harvesting conflicts with that of the small grains, and on the same farm the latter are given the preference. The corn should be planted on the lighter, sandy soils, care being given to maintain the moisture supply by frequent cultivation.

Potatoes are grown, but only for home use. The tubers are large, smooth and of fine quality. Following potatoes, very large crops of grain are obtained.

Cattle and hog raising is confined to a few farmers. The cattle are of the beef type, except a few that furnish the local dairy supplies. The native prairie is used for pasture, and swamp hay and ground small grains are fed in winter. The great bulk of the

feed is consumed at home by the many horses that are necessary in farming operations.

Except on a few of the best-managed farms, the manure from the stables is not applied to the land, though largely increased crop returns are realized from its use.

The moisture conditions determine the crop yields in this region, and those practices that concentrate the most moisture within reach of the plant roots give the best results. It is best to plan the management of the land with reference to dry seasons, since they are of more frequent occurrence, and in the wet years the same practices will give good results, though not much larger yields than result from less thorough methods under the prevailing conditions. Plowing to a depth of from six to eight inches provides a larger reservoir for moisture storage than shallower plowing and gives a larger space through which the plant roots may readily distribute themselves. The under part of the furrow slice should be well packed down, so that it will be in close contact with the unturned soil, which process aids in the distribution of water downward in times of rain, hastens the decay of organic matter and permits the plant roots to extend below the depth of plowing. The deeper the rooting the better can protracted drought be withstood. It should be the aim to get into the soil all of the water that falls and to retain it there until it can be taken up by the plants. To retain moisture the surface should not be left hard, rough or exposed any longer than is absolutely necessary. It is desirable to plow the land or disk the surface to the condition of a mulch as soon as the crop is removed, and if plowed it should be immediately worked down, and the surface kept loose and fine by the use of a shallow harrow. This applies particularly to fallow and fall plowing. It is said by some farmers that a loose, smooth surface in winter permits the fine top soil to blow and the snow to be carried away by the wind. If surface cultivation is practiced as soon as the soil is sufficiently dry not to puddle, the blowing will be prevented. The blowing of the snow does remove some moisture, but while it is melting the surface of the ground is frozen, so that a comparatively small amount enters the soil, and is more than balanced by the amount conserved by summer cultivation. It might be found advisable in some years to roughen the surface of the ground late in the fall, so that it would hold the snow.

It is recognized that even in dry seasons those crops that are cultivated seldom fail to make a good growth. This is largely be-

cause evaporation from the surface is checked by the loose top soil. Spring harrowing of the grains is practiced on at least two farms in the area with good results. The practice may be continued until the plants begin to joint or reach the stage when they completely shade the ground.

All of the above practices for the accumulation and retention of moisture are to be recommended, but it is recognized that it will not always be practicable to apply them completely. Their use must be governed by the question of economy in each case, but it is believed that if more attention be paid to the conservation of moisture considerably increased profits will result on many of the farms of the area.

AGRICULTURAL CONDITIONS.

The farmers of the Cando area are generally in a fairly prosperous condition. The number of really good houses is not large, although many of the farms have large, substantial barns, and within the last three years many fine farm buildings have been erected. On the remaining farms the buildings are the primitive "shacks" of the homesteading settler. Much machinery of modern patterns is used, and the horses and other live stock are of good types. The acreage of improved land is increasing, and the value of farm land has risen rapidly in the last five years. Much of the debt incurred only a few years ago in establishing new farms is being liquidated, and the amount of land offered for sale is constantly decreasing. The value of land ranges from about $10 an acre for the most remote prairie to $35 or $40 for the cultivated land near the shipping points.

According to the census of 1900, 76 per cent of the farms in Towner county are operated by the owners, and that figure probably represents conditions in the area surveyed. Renting, where practiced, is usually on a basis of a share of the crops, the proportion being one-half of the grains thrashed where the owner of the land furnishes half the seed and pays half of the threshing bill. At least one large farm is operated by a resident manager.

The average size of farms in the county in 1900 was 289 acres, but the average in the area surveyed will probably exceed that figure considerably. A large number of farms contain from 300 to 500 acres each, several exceed 1,000 acres, three or four exceed 2,500 acres, and one contains 4,300 acres. Land is handled on the

basis of the quarter section of 160 acres as a unit, and the price is often quoted by the "quarter."

A large amount of labor is required during part of the year when crops are being seeded and harvested, while at other times only a few men are employed. To meet this irregular demand large numbers of men are imported from other sections of the country. Those employed through the year are engaged by the month at a wage of from $25 to $35. Ordinary labor is paid from $2 to $3, and where skilled mechanics are employed their wages exceed these figures. Subsistence is also furnished to those employed.

All of the cultural operations are performed on an extensive scale, and each man is expected to handle wide-cutting implements and from three to eight horses. Plowing is done with a double gang plow drawn by five or six horses. Four horses are used in the ordinary binder, six in the rear-draft binders and headers, and four in the seeders.

The four grains, wheat, flax, oats and barley, occupied, in 1900, 99 per cent of the area of all cultivated crops, with relative acreages as follows: Wheat, 62.8; flax, 14.5; oats, 13.9; and barley, 7.9 per cent. Since that date there has probably been a relative decrease in the acreage of flax. Hay is produced from the swamp land and is a natural growth. Thirty-four per cent of the total value of farm products is placed on the market, the remainder being fed to live stock.

Since wheat is the principal product in the area, it is of interest to know the cost of producing a bushel of this grain. On one of the largest farms, where accurate records of operations and expenses had been kept for a series of ten years, the average yield per acre was ascertained to be about twenty bushels, and the cost of production and marketing, aside from a charge for rent on the land, amounted to 41 cents a bushel when 1,000 acres or more were grown, and nearly 47 cents when less than 500 acres were grown. As this farm is probably more carefully managed than the average farm, the cost of production is below and the yield above the average for the area. The soil on this farm is mainly the Clyde loam, with small bodies of Clyde fine sandy loam included.

No attention is paid to the adaptation of soil to crops. Crops are grown wherever the conditions will permit a fair growth to be obtained. The yields are largely influenced by the seasonal

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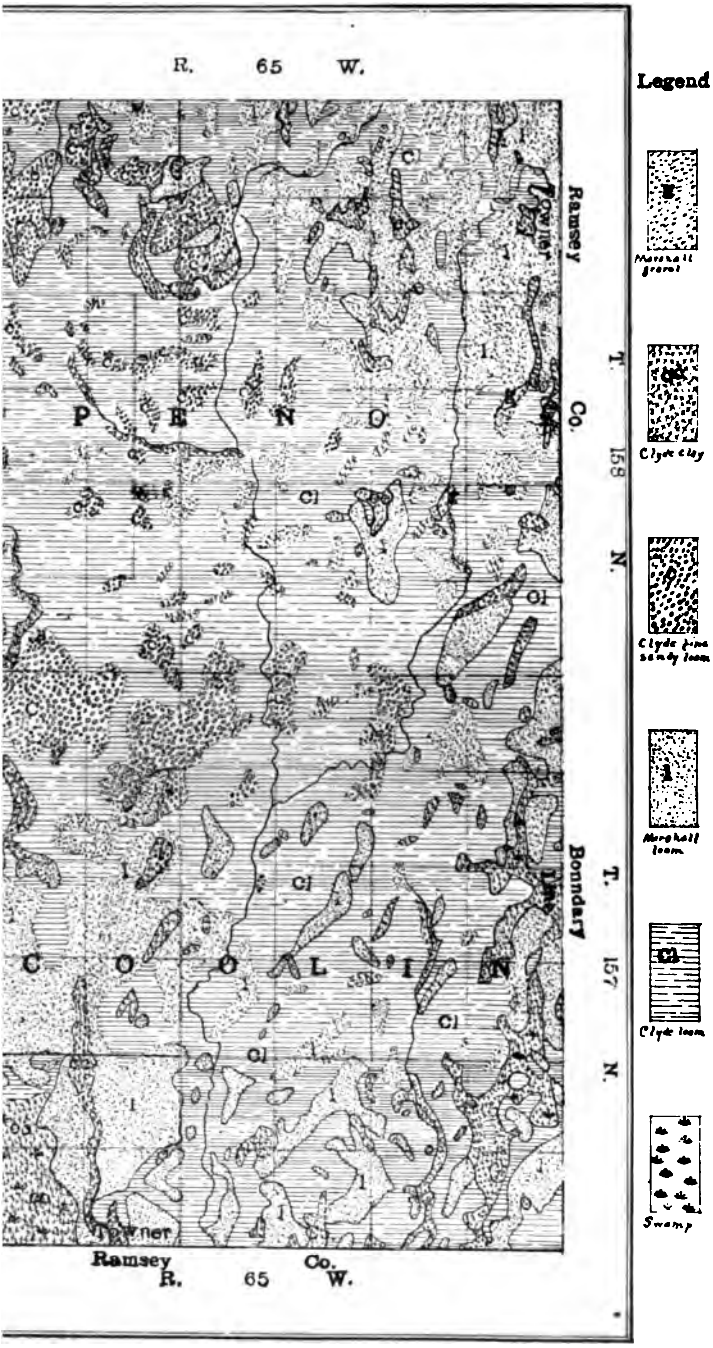

FIELD OPERATIONS BUREAU OF SOILS, 1904

moisture conditions, and the same land does not return the same yield year after year. The heavier lowland soil, embraced chiefly in the type Clyde loam, is the most productive for the grains. As a rule, flax succeeds best on the same type of soil, but in some places it is so damaged, it is thought, by the excess of lime in the soil that its growth is uneven.

As the region becomes more intensely cultivated the need of additional crops will be realized. Rape and root crops grow well on the heavier types, and corn and vegetables do best on the heavier parts of the sandy loam. It may be found that leguminous crops and additional grasses can be produced. Some excellent growths of white clover have been observed. These crops will be useful only should the raising of live stock become more important.

The Great Northern Railroad, with the St. John branch line, affords the only facilities for transportation of the products of the area to the markets, which for all of the principal crops are beyond the border of the state. The country road system is rectangular with a road legally on each section line, though in reality the roads are not so frequent, because the present population is not sufficiently dense to utilize so complete a system, while on many of the lines there are barriers to travel that can only be removed at large expense. The main roads through the county are improved by grading and bridges, but none of them is surfaced. Most of the heavy hauling of grain and of supplies for remote points is done in the winter when the ground is frozen.

Since the population is essentially an agricultural one, or dependent on agricultural interests, it necessarily follows that the local market for produce is very small. The grain goes east to the mills and to distributing points, and most of the supplies come in from the same source. There are ten elevators at Cando and four at Maza, through which the grain is handled. Most of it is sold directly to the elevator companies, but the farmer may ship his own grain, in which case, at a cost of 1½ to 2 cents a bushel, the elevator will receive, store to a limit of fifteen days, and place on board cars. Storage charges are 1 cent per bushel per month for short periods and a less rate for a longer time.

SOIL SURVEY OF THE CARRINGTON AREA, NORTH DAKOTA.

By A. E. Kocher and Lewis A. Hurst.

LOCATION AND BOUNDARIES OF THE AREA.

The Carrington area, comprising parts of Griggs and Foster counties, lies in the east-central part of North Dakota, between meridians 98 degrees and 99 degrees 15 minutes west longitude, and parallels 47 degrees 19 minutes 34 seconds and 47 degrees 30 minutes north latitude. The area is rectangular in shape, extending twelve miles north and south and sixty miles east and west, and contains 460,800 acres, or 720 square miles, of which 432 square miles are within the limits of Foster county and 288 square miles in Griggs county. It embraces townships 145 and 146 north and ranges 58 to 67 west, inclusive.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

Agriculture in the Carrington area had its beginning in 1880, when the first permanent settlement was made near the present site of Cooperstown. In 1882, when Griggs county was organized, with Cooperstown as its county seat, many immigrants from southern Michigan settled in the eastern part of the area. The following year settlement was greatly encouraged by the completion of the United States survey of the public lands and the building of branch lines of the Northern Pacific Railway from Sanborn to Cooperstown and from Jamestown to Carrington. During this year the towns of Carrington and Melville were founded by people from the east.

An industrious class of Norwegians, Danes and Swedes, a few years later, settled in the region west of Cooperstown, and have been an important factor in the development of the central part of the area.

From the beginning of agricultural operations in Foster county extensive tracts of land have been held by individuals or by private corporations. One of these large holdings, near Bordulac, has an

DEPAR HEET

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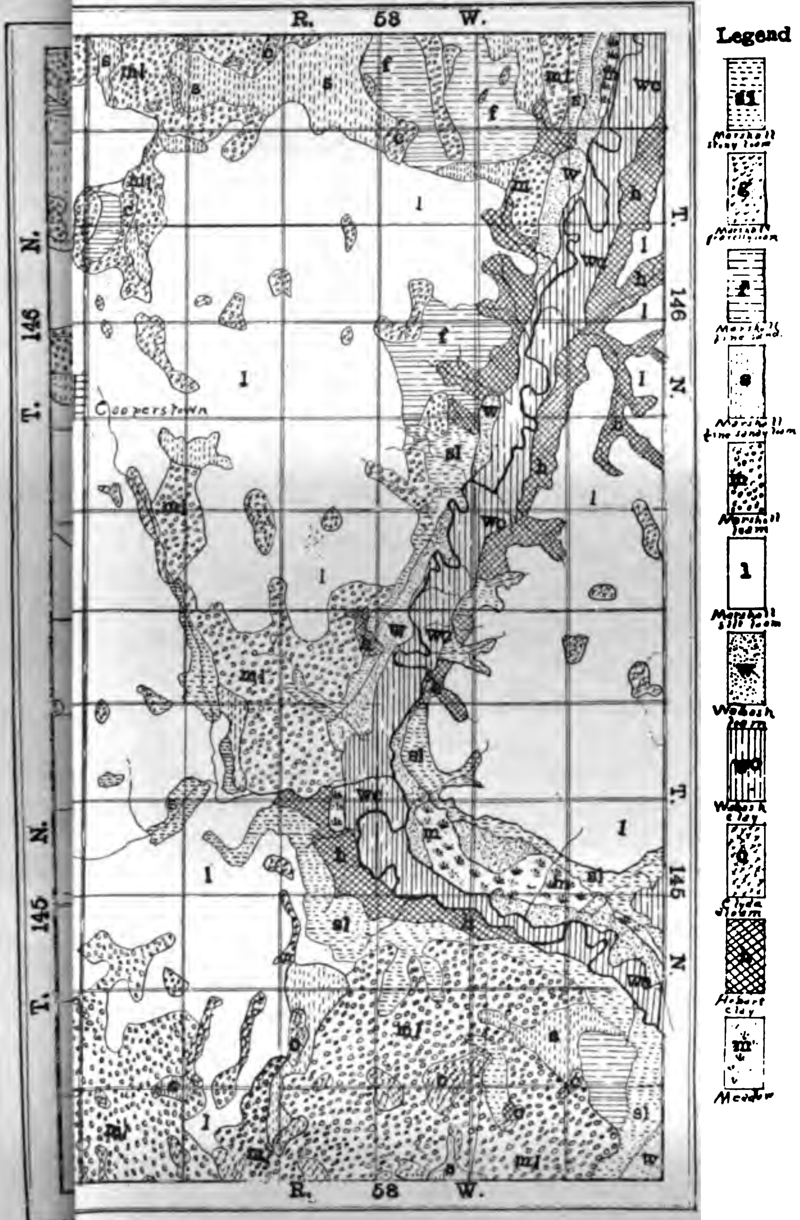


area of 10,000 acres under cultivation. Aside from this, only a small proportion of the public lands west of the James river had been taken up prior to 1896, but during that year and in 1898 many home seekers from Iowa and Indiana came into the area, and most of the unbroken prairie between Carrington and the river was put in cultivation. Also about this time a thrifty class of Turks and Russians settled in the southwestern corner of the area, among the foothills of the Missouri Plateau, and during their brief occupation of the land they have done much to increase the valuation of what was hitherto considered a very inferior soil.

In the early days the farming class was not so prosperous as in succeeding years, due mainly to the crude and ineffectual methods practiced during the seasons of excessive drought. Since then all farm methods have undergone a material change. The smoothing harrow and the old-fashioned broadcast seeder attached behind a wagon and drawn across the field have been replaced by the spring-tooth harrow and the modern press drill. These implements it has been found, make the seed-bed firm and conserve the soil moisture better, lessening the damage caused by long periods of drought.

Wheat, flax and oats, the crops which held first place in the rotation twenty years ago, are still the dominant crops of the area. There is, however, a decided tendency to introduce some new crops. Corn, a needed cereal, is beginning to be grown, and alfalfa, clover and the tame grasses have been lately introduced with success.

CLIMATE.

The climate of the area is quite varied. In the winter the temperature sometimes falls to 50 degrees below zero, while in the summer it has been recorded as high as 107 degrees, giving an extreme range of 157 degrees. The summer months are usually very pleasant, the temperature rarely rising above 90 degrees, and the nights are usually cool.

The spring and fall months are usually characterized by high winds, which, beginning in the morning, increase in force until about 2 o'clock p. m., then gradually slacken and abate with the setting of the sun.

There is only one weather bureau station within the area, which is located at Melville, but for purposes of comparison the records of the Jamestown and Devils Lake stations are also given.

The following table shows the normal monthly and annual temperature and precipitation:

Normal monthly and annual temperature and precipitation.

Month	Melville		Devils Lake		Jamestown	
	Temperature—Deg. F.	Precipitation—Inches	Temperature—Deg. F.	Precipitation—Inches	Temperature—Deg. F.	Precipitation—Inches
January	12.0	0.12	8.0	0.27	9.0	03.0
February	6.0	.12	4.0	.60	9.0	5.6
March	26 0	.32	17.0	1.06	19.0	10 0
April	43.0	.85	41.0	.95	42.0	22.1
May	55.0	1.30	52.0	1.68	53.0	29.8
June	62.0	7.30	64 0	3.38	65.0	42.1
July	62.0	2.03	69.0	4.12	70.0	22.4
August	64.0	.20	65.0	2.34	67.0	12.8
September	54.0	1.46	59.0	.57	58.0	9.3
October	43.0	2.10	42.0	1.84	46.0	18.9
November	26.0	.20	28.0	.35	22.0	12.5
December	11.0	.25	10.0	.20	16.0	7.4
Year	38.8	16.25	38.2	17.36	39.7	19.69

Notwithstanding that the normal annual rainfall is rather light, especially as recorded at the Melville station, the fact that such a large proportion of it comes in the growing season usually makes the amount sufficient for crop production.

According to the records of the above station, one-half of the normal annual precipitation for the last seven years has fallen during the months of May and June, and the total normal precipitation from November 1 to April 1 has been only 1.01 inches. Though these figures are somewhat more striking than those presented by the Devils Lake and Jamestown stations, and may perhaps exaggerate to some extent the conditions in the eastern part of the area, they emphasize the fact that the average snow fall of the region is very light indeed.

From data relating to the dates of the last killing frosts in spring and the first in fall, as afforded by the records of the same weather bureau stations, the average date in spring is shown to be May 28 and in fall September 12. The average length of the growing season, based on frost occurrences during the last seven years, was 106 days at Melville and Jamestown and 109 days at Devils Lake.

PHYSIOGRAPHY AND GEOLOGY.

The topographic features of the Carrington area are those characteristic of glaciated regions. Two extensive systems of moraines, extending in a northerly and southerly direction, divide the area into three distinct and comparatively level tracts. One of

these moraines, occurring in the vicinity of Cooperstown, has an average width in the area of about four miles, although just before crossing the northern boundary, its course becoming east and west causes it to occupy the northern tier of sections in both Cooperstown and Clearfield townships. In this locality the topography is rough and broken, the hills rising abruptly from the plains to a height of thirty to 100 feet. South of Cooperstown the morainic belt becomes narrower and the hills less pronounced.

East of this region to beyond the limits of the area extends a gently undulating plain, through which the sluggish Sheyenne river crosses the area from north to south. Here the valley, cut in glacial times, has an average width of about one-half mile, and lies 100 feet or more below the level prairie. With the exception of one big bend the course of the river in the main is straight, but its feeble current along the level bottom causes it to wind from side to side of the valley. In the southern part of the valley are several old channels marked by sloughs and shallow lakes, through which the river still flows in times of high water.

The second and more important moraine is found just east of the center of Foster county, where it occupies probably 100 square miles of the area. Geologically this region is known as the fourth or Kiester moraine, and is of interest in that it forms the high walls of the glacial valley of the James river. Although about equal parts of this moraine lie on each side of the river, yet in surface features they present a striknig contrast. East of the river for about four miles the country consists of rounded hills and low ridges, separated from each other by gently sloping tracts. The altitude varies from 1,500 to 1,560 feet above sea level and from twenty to sixty feet above the prairie to the east. West of the river the surface of the first two miles is rough and broken in the extreme. The elevation varies from 1,520 feet, the level of the prairie, to 1,690 feet near the northern limit of the area. The valley of the river, with an autitude of 1,130 feet, lies about 100 feet below the level of the prairie and 260 feet below the summit of the moraine.

East of the James river, between the two morainic belts already described, there is a gently rolling plain constituting about one-third of the entire area mapped. Near its eastern edge this plain is cut in a southeasterly direction by the deep channel of the Baldhill creek. At the present time this stream is small and unimportant,

but when the glacier's edge stood a few miles to the north, where now the moraine belt is found, a mighty river hurried down its course, cutting out the broad, deep valley with the water from the ice.

The remaining great physical division of the area extends westward from the moraine along the James river to the foot of the Missouri Plateau, of which the outlying hills of Hawks Nest just touch the southwestern corner of the area. This broad plain is characterized by a slightly rolling surface, marked in the western part by the intermittent channel of Pipestem creek, numerous hay meadows and sloughs.

The entire area during the glacial period was covered by the ice, which on melting left its burden of sand, silt and clay scattered on the surface. This glacial till or drift varies in the area from ten to 200 feet or more in depth, and because of the comparatively light rainfall since its deposition the surface features have been but slightly modified. Below the drift there lies a bed of Cretaceous shale, which along the Sheyenne river valley comes within from ten to twenty feet of the surface of the prairie. The soils resulting from this formation are very heavy and are considered among the most productive in the area.

SOILS.

Twelve distinct types of soils were recognized and mapped in the Carrington area. The following table shows the name and extent of each:

Areas of different soils.

Soil	Acres	Per cent	Soil	Acres	Per cent
Marshall silt loam.......	230,128	50.2	Marshall fine sand	4,096	1.0
Marshall loam...........	114,560	26.3	Wabash clay............	3,328	.9
Clyde loam...............	24,768	5.5	Hobert clay.............	2,496	.6
Marshall stony loam	23,936	5.2	Marshall gravelly loam.	1,920	.5
Marshall fine sandy loam	21,696	4.9	Wabash loam...........	1,536	.4
Meadow	16,964	3.2			
Carrington clay loam....	6,272	1.2	Total..........	460,800	....

MARSHALL LOAM.

The Marshall loam to an average depth of about ten inches consists of a dark brown friable loam, underlaid usually by a grayish-brown silty clay, becoming slightly yellow in the lower depths.

(a) CARRINGTON, FROM THE NORTH.

Marshall loam shown in foreground. (See p. 102.)

(b) WHERE THE SOO RAILWAY CROSSES THE JAMES RIVER.

East of Carrington.

The type is found in all parts of the area occupied by moraines and in the level prairie along the courses of the streams. The most extensive body of this type occupies the hills just west and south of Cooperstown and a large portion of the level prairie bordering Baldhill creek. It also occurs between the areas of Marshall silt loam and Marshall stony loam along the James river and in the vicinity of Pipestem creek south and west of Carrington.

The level and rolling topography gives rise to slightly different phases of the type. The hilly phase, described above, is the more important by reason of its greater extent. The level phase near Baldhill creek consists of about twenty inches of dark brown loam underlaid with yellowish brown fine sandy loam or shaly loam and sand.

The porous subsoil gives the phase adequate subdrainage, which in seasons of slight rainfall is apt to be excessive, while the sloping surface of the hilly phase gives that portion of the type ample surface drainage.

The Marshall loam is of glacial origin, the hilly phase having been deposited along the front of the melting ice. On the prairie near the course of Baldhill creek the sandy phase is probably a glacial overflow, the deposit being made by the waters hurrying southward at the time when the front of the ice sheet halted in the morainic region a few miles to the north. On the higher elevations, where the finer material has been removed by rains, the soil is shallow and has a relatively high content of fine sand and gravel, but these areas are of very small extent.

Until recently a part of the type was used as pasturage for herds of cattle and sheep, but the stock-raising industry is now confined to the stony hills along James river.

Wheat and flax have always been the leading crops on the Marshall loam, the yields averaging fifteen and twelve bushels per acre, respectively. Oats yield from thirty to sixty bushels per acre. Barley, rye and speltz also do well and are extensively grown, although the last named is but newly introduced. For the growing of potatoes, corn and garden truck this soil is unexcelled in the area. Potatoes yield from 150 to 250 bushels per acre and are of excellent quality. However, at present this crop is grown only for home consumption. The average yield of corn in favorable seasons is about forty bushels per acre.

The value of the hilly phase of the type ranges from $15 to $25 an acre, while that of level topography in the more desirable locations sells at from $20 to $30 an acre.

The following table gives the average results of mechanical analyses of typical samples of the soil and subsoil of this type:

Mechanical analyses of Marshall loam.

Number	Description	Fine Gravel —Per Cent	Coarse Sand —Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent.	Silt—Per Cent	Clay—Per Cent
12803, 13405. 13407..........	Soil....	1.8	8.5	6.9	27.3	15.7	27.3	12.2
12804, 13406, 13408..........	Subsoil	1 9	6.1	4.6	19.3	13.0	29.7	25 1

MARSHALL SILT LOAM.

The soil of the Marshall silt loam to a depth of from ten to sixteen inches consists of a dark brown to black silt loam, resting upon a yellowish brown silty clay subsoil, usually several feet in depth.

The Marshall silt loam is by far the most extensive soil type mapped, occupying about one-half of the area surveyed. It occurs in three large bodies, each broken into by the less extensive types. One of these bodies occupies the level land near Cooperstown, another is found between Baldhill creek and the hilly region along the James river, and the third occupies the major portion of the prairie west of Bordulac.

The type consists of two closely related phases passing so gradually into each other that no consistent boundary line between them can be drawn. That portion of the type in the eastern part of the survey is a somewhat heavier soil than that found west of the James river. Near Bordulac and in the vicinity of Carrington areas are found where the soil consists of about fourteen inches of black silt loam containing a small percentage of fine sand. The subsoil is a silty clay, varying in color from light brown to white. The areas of white, limy subsoil, as a rule, are not quite so productive as are those in which the lime occurs in less amounts.

The Marshall silt loam has usually a level surface. Now and then low swells occur from ten to twenty feet in height, which give the type a slightly undulating appearance, but nowhere is the topography so rough as seriously to interfere with cultivation.

The type usually has sufficient drainage, though for the cultivation of the deeper rooted crops the low-lying level portion of the prairie would be greatly benefited by open ditches or tile drains.

The origin of the Marshall silt loam dates back to glacial times, when the material was deposited by the melting of the ice. Owing to the light rainfall of the region, little evidence is seen of subsequent erosion. Along the edges of deep coulees and on the summits of the hills, where the rains have carried off the finer particles of earth, a little sand is frequently encountered and the silty subsoil comes within a few inches of the surface; but these areas occur in strips too narrow to be represented on the map.

The type retains moisture well and is one of the most valuable soils in the area. In the vicinity of Carrington cultivated lands sell for from $20 to $30 an acre, while in the eastern part of the area cultivated farms command from $26 to $40 an acre.

The Marshall silt loam has been devoted mainly to the growing of small grains, though it is well adapted to a variety of crops. Alfalfa wherever tried has done well, and red clover, timothy and brome grass have given excellent results.

Wheat, the chief crop grown, yields from twelve to thirty bushels per acre, the average being about fifteen bushels. Flax yields from ten to sixteen bushels per acre, oats from thirty-five to seventy bushels and barley, rye and speltz in like proportions.

The following table gives the arevage results of mechanical analyses of samples of the Marshall silt loam:

Mechanical analyses of Marshall silt loam.

Number	Description	Fine Gravel —Per Cent.	Coarse Sand —Per Cent	Medium Sand —Per Cent	Fine Sand Per Cent	Very Fine Sand Per Cent	Silt —Per Cent	Clay —Per Cent
12923,13409,13411	Soil. ..	1.2	3.5	2.5	10.5	13.3	50.3	18.7
12924,13410,13412	Subsoil.	1.3	5.0	3.0	11.0	14.0	42.9	22.7

CLYDE LOAM.

The soil of the Clyde loam is of a varying texture, ranging from a dark brown loam to black clay loam, with an average depth of ten inches. The subsoil is usually a gray or drab-colored clay to a depth of thirty inches, below which are frequently found thin layers of coarse sand.

A phase of the type of quite common occurrence consists of a black, heavy sandy loam, underlaid at from four to ten inches by a sticky white silty clay.

The Clyde loam is of wide distribution throughout the area, occurring as numerous low depressions ranging from a few rods in extent to several hundred acres. The type marks the location of old lake beds, which, lying below the general level of the prairie, are always poorly drained. Around the margin of these old lakes well-marked beaches frequently occur from five to twenty feet in height, composed of coarse sand, gravel and large glacial boulders. This sandy, wind-blown material has greatly changed the texture of the soil in some of the smaller depressions.

For centuries these lake beds have received the drainage of the surrounding prairie and having no outlets the only avenue for the removal of the waters was by evaporation. Thus the salts held in solution by the waters of the lake were left behind and have collected in the lowest places as a white efflorescence on the surface. However, only rarely is alkali encountered in sufficient quantities to interfere seriously with the growth of native vegetation. The soil is frequently too wet for cultivation, and only about 1 per cent of the type has yet been broken up. Where alkali is found on the cultivated areas, the application of barnyard manure has greatly improved the structure of the soil, allowing the rains to carry the salts to the lower depths beyond the reach of the shallow-rooted crops.

The type in favorable seasons supports a luxuriant growth of native grasses, but if the rains come late in the spring the grasses do not make a vigorous growth, and in some years when ready to be cut for hay many acres are so wet as to prevent the harvesting of the crops. The greater part of the land of this type is held at about $15 an acre.

The following table shows the average results of mechanical analyses of typical samples of the soil and subsoil of this type:

Mechanical analyses of Clyde loam.

Number	Description	Fine Gravel —Per Cent	Coarse Sand —Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13415, 13417	Soil....	1.0	1.4	1.6	12.4	17.5	42.9	23.1
13416, 13418	Subsoil	1.2	4.8	4.1	8.9	14.6	38.4	27.9

(a) A HOMESTEADER'S RESIDENCE, NORTHEAST OF CARRINGTON.

(b) A RUSSIAN HOMESTEADER'S RESIDENCE SOUTHWEST OF CARRINGTON.

MARSHALL FINE SAND.

The Marshall fine sand is an incoherent, dark brown or black fine sand, slightly loamy on account of the presence of organic matter, grading at twelve to sixteen inches into a lighter colored, less coherent fine sand, and this in turn, at twenty-four inches, is underlaid by a yellow or gray sand of fine to medium texture.

The type occupies gently rolling prairie land and is primarily glacial in its origin, being deposited by the melting of the glaciers or carried by their waters. Most of the type lies adjacent to or in the vicinity of river courses. The largest bodies were found just west of the Sheyenne river and in township 146 north, range 61 west, in the vicinity of Baldhill creek. A few small bodies are found in other parts of the area.

The soil, on acount of its loose texture, is easily transported by the wind, being carried sometimes to a considerable distance, and is often found in dunes from two to three feet in depth. Crops are often materially damaged by these sand storms, which often occur in the spring about the time the young grain is putting forth its tender shoots.

Only a small percentage of the Marshall fine sand is under cultivation. The native vegetation is less vigorous than that of the heavier prairie soils, and, except in very wet seasons, the crop yields are rather poor, ranging from six to eight bushels of flax per acre, eight to ten bushels of wheat, and from twenty to twenty-five bushels of rye, oats or barley.

The value of this type of soil varies from $15 to $25 an acre, depending upon its location and proximity to the heavier soils of the area.

The following table gives the results of mechanical analyses of typical samples of the soil and subsoil of the Marshall fine sand:

Mechanical analyses of Marshall fine sand.

Number	Description	Fine Gravel Per Cent	Coarse Sand —Per Cent	Medium Sand Per Cent	Fine Sand—Per Cent	Very Fine Sand-Per Cent	Silt—Per Cent	Clay Per Cent
12921	Soil	0.3	1.8	3.7	52.6	17.7	16.5	7.3
12922	Subsoil	.3	1.1	3.0	55.3	18.8	13.5	8.1

MARSHALL FINE SANDY LOAM.

The Marshall fine sandy loam, to an average depth of fourteen inches, is a dark brown or black loam or fine sandy loam, the color being due to the presence of organic matter. This is underlaid with a yellowish brown fine sandy loam less coherent in structure, grading at twenty inches or more into a yellow fine to medium sand, extending several feet in depth. Overlying the coarser material of the subsoil is often a thin stratum of shale, which when decomposed contains a small percentage of bluish gray clay. This is particularly true of the large body of this type in township 146 north, range 60 west. The subsoil is also frequently a loam.

The Marshall fine sandy loam usually occurs in small patches, the largest continuous bodies being in township 146 north, range 60 west, and range 61 west. In the former the texture of the soil is coarser than in other parts of the area. Disconnected bodies of the type also occur in township 146 north, range 61 west, and range 62 west, and in the vicinity of the Sheyenne river and Baldhill and Pipestem creeks. Another area, occupying parts of three sections, is found south and west of Melville. The type usually occupies gently undulating prairie or small morainic hills or plateaus. It frequently occurs also in narrow bands encircling old lake beds and along stream courses, but these were not of sufficient extent to be shown on the accompanying map.

The soil is of glacial origin, although the winds may have been a factor in its disposition. In the vicinity of the streams or between them and the series of moraines to the north of the area it is reasonable to suppose that this soil was deposited as overwash from the melting of the ice of the glaciers or carried down by the waters off the moraines themselves.

Owing to the fairly loose structure of both soil and subsoil and location in the vicinity of stream courses and old lake beds, the Marshall fine sandy loam is naturally well drained, but it is sufficiently compact to retain enough moisture to withstand drought. In extreme wet or dry seasons it frequently gives better yields of grain than the heavier types, and the crops are less suceptible to rust, but in average seasons the yield is less. The type is particularly well adapted to Irish potatoes, the yields being from 150 to 250 bushels per acre. Corn also does well on this soil, but is grown only in small gardens for home use. Each of the cereals grown in the area is found upon the Marshall fine sandy loam,

with average yields per acre as follows: Wheat, ten to fifteen bushels; flax, six to ten bushels, and rye, barley or oats, twenty-five to thirty bushels.

Land of this type ranges in price from $20 to $30 an acre.

The following table gives the average results of mechanical analyses of typical samples of soil and subsoil of the Marshall fine sandy loam:

Mechanical analyses of Marshall fine sandy loam.

Number	Description	Fine Gravel—Per Cent	Coarse Sand—Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
12801, 13402	Soil....	1 7	11.1	9.1	28.3	17.2	21.1	11 2
12802, 13404	Subsoil	6	5.7	7 8	27.0	15 4	32.1	11.1

WABASH CLAY.

The soil of the Wabash clay consists of a dark brown or black clay loam or clay, with an average depth of about twelve inches. The subsoil is usually a black heavy clay, from twelve to thirty inches deep, underlaid to a considerable depth by a light brown clay of the same texture. The soil is tenacious and rather difficult to work, especially in the spring, when it is often saturated by the seepage waters from the higher levels.

The Wabash clay, averaging one-half mile in width, is found along the lowest portions of the Sheyenne river valley. In the northern part of the valley, where the type lies chiefly on the eastern side of the river, there is a gentle slope from the higher elevation to the water's edge, but farther south, where the strip becomes more narrow and follows more nearly the river's course, the surface is quite low and level. In this level portion, where the water sometimes saturates the soil, open ditches could be dug or tile drains laid with profit. The greater part of the type, however, is well drained and under a fair state of cultivation.

The Wabash clay is of alluvial origin, having been formed by the deposition of the fine particles washed down from the heavy Hobart clay of the adjoining hillsides.

The heavy texture of the soil and its low-lying position along the river, insuring sufficient soil moisture for crops to withstand drought, make the type admirably adapted to small grains and

tame grasses, although the latter have not yet been extensively introduced. Wheat, under favorable conditions, yields from twenty to thirty-five bushels per acre, oats from thirty-five to seventy bushels, and flax, rye and barley do remarkably well.

Along the course of the river and the old glacial channels which wind through the valley, occurs a narrow strip covered by a dense growth of oak, ash and elm. This growing timber, in a region where fuel is so scarce, makes this type of soil one of the most valuable in the area, and because the valley is so badly broken into by the tortuous channel of the river, this portion of the type is probably more valuable in its present state than it could possibly be under cultivation.

The price of the land ranges from $30 to $40 an acre, depending upon improvements.

The following table shows the average results of mechanical analyses of samples of the Wabash clay:

Mechanical analyses of Wabash clay.

Number	Description	Fine Gravel—Per Cent	Coarse Sand—Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13000, 13421	Soil	0.2	1.3	1.2	5.6	6.7	48.2	36.3
13001, 13422	Subsoil	.1	1.1	.8	3.2	4.4	35.1	55.1

HOBART CLAY.

The Hobart clay, though small in extent, may be said to have three distinct phases, depending upon the declivity of the bluffs along which it occurs.

At the top of the bluff the soil consists of from none to six inches of brown clay loam, underlaid to about four feet by dark drab or slate colored clay. Along the steeper part of the hill and that portion of the valley where erosion has been most active the clay loam has been entirely washed away, leaving the stiff, waxy, slate-colored clay exposed. At about the fourth foot the subsoil begins to pass gradually into shale, which soon gives place to the unweathered Cretaceous rock. On this phase of the type the surface is usually thickly strewn with large glacial boulders. Nearer the valley, where the slope is more gentle, the soil consists of about ten inches of friable clay loam, underlaid to a considerable depth by black, plastic clay.

(a) A GLACIAL CHANNEL (PIPESTEM VALLEY).

West of Carrington. Standing pool of water; there is no active stream in the large valley.

(b) HAY MEADOW IN PIPESTONE VALLEY, 6 MILES WEST OF CARRINGTON

Crossed by the Denhoff branch of the Northern Pacific railroad. The soil type is that of the Carrington clay loam.

The Hobart clay occurs along the precipitous bluffs of the Sheyenne river and the steep-sided coulees leading into it. Of the eroded phase the most typically developed area is found five and one-half miles southeast of Cooperstown, where the slippery clay and decomposing shale slide down the hill with every heavy rain, leaving the surface devoid of any vegetation.

Owing to its position, the stiff, waxy nature of the soil, and the numerous glacial boulders scattered over the surface, only that phase of the type which occupies the lower portion of the hill can be used for cultivation. Such a strip occurs near the northern boundary of the area on the east side of the river, and fine yields of all the small grains are annually produced. Where the Hobart clay is under cultivation the land is held at about $30 an acre, but the greater part of the type, used only for pasture, is valued at from $10 to $15 an acre.

The following table gives the average results of mechanical analyses of typical samples of the soil and subsoil of Hobart clay:

Mechanical analyses of Hobart clay.

Number	Description	Fine Gravel—Per Cent	Coarse Sand—Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13026, 13395	Soil....	2.9	6.9	3.9	12.4	4.4	30.9	38.4
13027, 13396	Subsoil	1.4	4.9	2.1	4.1	1.9	17.4	67.8

WABASH LOAM.

The Wabash loam, from none to seven inches, consists of a dark brown friable loam, with a considerable admixture of fine sand and silt, underlaid by a subsoil usually of the same texture and color as the soil, but becoming somewhat lighter in color below the second foot.

Only a few small areas of Wabash loam were encountered, these occurring as narrow strips within the Sheyenne river valley. The type occupies the more gently sloping portions of the valley and is an intermediate type between the Marshall stony loam of the bluffs and the Wabash clay of the valley floor. On the outer bends of the river, where the stream approaches the sides of the valley, the type extends down the slope to the bank of the stream, the elevation ranging from five to thirty feet above the high water mark.

The Wabash loam is one of the best drained soils in the area, and yet rarely suffers from the effect of drought. The type has been formed from the materials washed down from the Marshall stony loam and the prairie types adjoining. The soil is of comparatively recent origin, and owing to its position is constantly undergoing change, as the rains bring down materials from the bluffs or carry away materials previously deposited.

The Wabash loam is a very productive soil, and because of its excellent drainage features and the ease with which it can be cultivated it is well adapted to the production of truck crops. However, owing to the lack of convenient markets, no attempt has yet been made to grow these crops, except as they may be needed for family use.

Practically all of the type is cultivated to the small grain crops. Wheat yields from eighteen to twenty-five bushels per acre, though in exceptional years as high as thirty-five bushels have been reported. Oats produce from thirty-five to sixty-five bushels per acre, and the other grains in like proportion. The type is valued at $30 an acre.

The following table shows the results of mechanical analyses of the Wabash loam:

Mechanical annalyses of Wabash Loam.

Number	Description	Fine Gravel —Per Cent	Coarse Sand —Per Cent	Medium Sand —Per Cent	Fine Sand —Per Cent	Very Fine Sand-PerCent	Silt—Per Cent	Clay—Per Cent
13419	Soil	0.8	2.9	1.4	12.1	13.6	40.9	28.2
13420	Subsoil	.8	2.9	1.3	11.7	13.7	38.3	31.2

CARRINGTON CLAY LOAM.

The Carrington clay loam in its lowest lying phase consists of from none to ten inches of dark brown to black clay loam, underlaid to forty inches with yellowish brown silty and sometimes sandy clay. Below this depth the material is a brownish yellow clay, with an occasional thin layer of coarse sand. This phase of the type occupies the narrow valley of Pipestem creek and the hay sloughs in the western part of the area. Its origin is largely sedimentary, the material having been left by the waters of the stream or deposited as beds of former lakes.

The upland or prairie phase of the Carrington clay loam is a brownish yellow silty clay with an average depth of about ten inches. The subsoil ranges from material of the same texture and color to stiff, tenacious, dark gray clay. Between the third and fifth foot strata of reddish yellow sand are frequently encountered, containing varying quantities of calcium carbonate, gypsum and iron sulphate. The soil when wet is sticky and plastic and presents all of the objectionable features of "gumbo," making it a dfficult soil to till.

The type is of comparatively limited extent, being found only in small bodies in townships 145 and 146 north and ranges 66 and 67 west, inclusive. South of Carrington, along the Devils Lake branch of the Northern Pacific Railway, occurs the most typical area of the prairie phase of the type. Here small irregular areas are frequently found from which the original prairie sod has been removed. This condition is commonly believed to have been caused by early prairie fires, and although it may be due to other causes there was not time to investigate this question sufficiently to determine the point definitely. On most of these areas a new sod has been developed, but the vegetation makes a feeble growth at best.

The Carrington clay loam is the only soil in the area seriously affected with alkali. Practically all of the type contains some salts, though not in sufficient quantity to interfere seriously with the growth of native grasses. Only about 1 per cent of the type is under cultivation, and in the cultivated fields small places are occasionally found, ranging from a few rods to two or three acres in extent, where the alkali has risen and formed a white crust on the surface. On such spots vegetation has been entirely killed out.

The most effective way to correct permanently the alkali conditions in this soil is by the construction of an artificial drainage system. Deep open ditches are a necessity, as the structure of the soil is such as to preclude the probability of satisfactory results by the use of tile drains. The structure of this soil has in many instances been much improved by the application of barnyard manure, the injurious effects of the alkali having disappeared and the soil made to produce good yields of grain the second season following manurial treatment.

This type of soil is valued at from $9 to $15 an acre.

The following table shows the average results of mechanical analyses of samples of this soil:

Mechanical analyses of Carrington clay loam.

Number	Description	Fine Gravel—Per Cent	Coarse Sand—Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13386,13389,13392	Soil	1.3	3.2	3.6	13.6	15.4	31.4	31.0
13387,13390,13373	Subsoil	.9	2.8	3.5	15.7	19.1	31.0	26.

MARSHALL GRAVELLY LOAM.

The Marshall gravelly loam contains a high percentage of rounded quartz and granitic gravel, ranging from one-half inch to two inches in diameter. The interstitial material usually consists of coarse sand and incoherent shale, which, at a depth of three feet, give place to a yellow silty loam.

This type is found only in small areas on the summits of the higher hills and ridges. The largest of these areas, which does not much exceed one square mile in extent, occurs northwest of Cooperstown in portions of sections 5 and 6 of township 146 north, range 60 west.

Owing to its rough topography and the loose texture of the soil, the Marshall gravelly loam is little used for cultivation. However, on a few of the lower ridges fair yields of the small grains are sometimes secured. The value of the type ranges from $10 to $15 an acre.

The following table gives the results of mechanical analyses of samples of the Marshall gravelly loam:

Mechanical analyses of Marshall gravelly loam.

Number	Description	Fine Gravel—Per Cent	Coarse Sand—Per Cent	Medium Sand—Per Cent	Fine Sand—Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13399......................	Soil....	6.6	28.3	10.1	19.0	7.1	14.4	14.3
13400......................	Subsoil	9.5	24.5	9.5	13.5	8.3	19.1	15.6

MARSHALL STONY LOAM.

The soil of the Marshall stony loam is usually a dark brown fine sandy loam or loam, with an average depth of about ten inches. The subsoil of the greater part of the type consists of a light brown silty loam or silty clay, reaching many feet in depth.

Scattered over the surface and sometimes deeply embedded in the soil are found numerous granitic glacial boulders, ranging from a few inches to ten feet or more in diameter. In some localities, where the rains have washed the finer soil away, the boulders have been left as a virtual pavement over the surface of the ground and only sand and gravel occupy the interstitial spaces.

Though the type is found in small, irregular patches throughout the survey, only two areas of very large extent were mapped. The largest of these occurs along the banks of the James river, occupying the greater proportion of the high morainic hills. In this locality small areas are found on which few stones occur, but these, being of rough topography and small in extent, were mapped as a part of the more stony phase of the type. The next most extensive area occupies the foothills of the Missouri plateau, in the southwestern corner of Foster county. Small areas occur along the bluffs of the Sheyenne river and among the moraines just west of Cooperstown.

The surface of the Marshall stony loam is naturally very rough and broken, a common feature being the frequent occurrence of "hay sloughs" surrounded by irregular hills. Much of the soil has excessive drainage, as the slight rainfall, instead of being retained on the steep hillsides, quickly runs off and is lost in the heavier soils of the depressions.

The origin of the type is purely glacial, the high moraines and long, smooth swells and ridges marking the place where the edge of the melting ice sheet halted in its slow retreat across the area.

One phase of the Marshall stony loam consists of large stones embedded in coarse sand and fine gravel. This phase occupies the summits of the higher hills or occurs as narrow strips around the margins of old lakes. In either case it has no agricultural value. In a few instances, where the stones appear only on the surface, the owner has removed them, and when this is done the soil is fairly productive. However, only a small per cent of the Marshall stony loam is under cultivation, being considered more profitable to utilize the type for grazing purposes than to incur the expense of removing the stones.

Along the James river the hills support at nominal cost throughout the summer a herd of several hundred cattle, and a considerable income is realized by some of the farmers from the cattle industry.

The value of the Marshall stony loam varies from $8 to $15 an acre, depending upon location and topography.

The following table gives the results of mechanical analyses of typical samples of the Marshall stony loam:

Mechanical analyses of Marshall stony loam.

Number	Description	Fine Gravel —Per Cent	Coarse Sand —Per Cent	Medium Sand —Per Cent	Fine Sand —Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
3397................	Soil	7 7	12.8	7.3	19.4	14.7	24.3	13.6
3398	Subsoil......	1.7	11.8	7.4	18.3	15.0	33.5	19.3

MEADOW.

Meadow is composed largely of coarse sand, underlaid at varying depths with gravel, shale and cobblestones. In some localities the soil contains a small amount of silt and clay, overlying always a subsoil of loose texture.

The type occurs in small irregular areas along the present courses of the streams and the unused waterways of glacial times.

Along the James river, near the northern boundary of the area, occurs about 1,600 acres of the type, of which nearly one-half has been put in cultivation. During wet seasons fair crops of grain are produced, but the frequent occurrence of large, glacial boulders on the surface interferes to a great extent with cultivation. From this body down through the valley extends a narrow strip, in which occur a few small areas of very desirable soils, adapted to the usual crops grown, but these were of too small extent to be classified as a new type.

In the southwestern part of the area another extensive body of meadow is found deposited as glacial wash on the more gentle slope at the foot of the Missouri plateau. Here the loamy material, from ten to fifteen inches deep, gives the type the appearance of good, productive soil, but the underlying gravel and cobblestones make it very susceptible to the effects of drought.

The type, whether cultivated or used for pasture, is valued at from $10 to $15 an acre.

The following table shows the results of mechanical analyses of samples of the meadow:

Mechanical analysis of Meadow.

Number	Description	Fine Gravel —Per Cent	Coarse Sand —Per Cent	Medium Sand —Per Cent	Fine Sand —Per Cent	Very Fine Sand—Per Cent	Silt—Per Cent	Clay—Per Cent
13022	Soil	3.2	30.6	20.6	14.3	4.3	11.3	15.1
13023	Subsoil	9.2	43.0	25.9	13.3	.9	2.4	5.2

ALKALI IN SOILS.

Alkali in injurious quantities was found only in the southwestern part of the area. The small bodies of Carrington clay loam, which occur south and west of Carrington, are all more or less impregnated with alkali, though this is the only soil in the area which is seriously affected. Only portions of these bodies contain alkali in sufficient quantities to prevent the growing of ordinary crops. These strongly impregnated spots, occurring usually in the center and lowest portions of the type, vary in size from a few rods across to two or three acres in extent, and are commonly marked either by badly stunted crops or by the entire absence of vegetation.

Samples of the soil and subsoil were taken from the worst alkali areas and the character and quantity of the salts present determined in the chemical laboratory of the Bureau. The results of the analyses, given here in tabular form, show that the salt content in these areas is sufficiently high to interfere with the growth of ordinary crops. The principal salt found is sodium sulphate, although there are also present considerable quantities of sodium carbonate, a salt especially harmful to plant growth. The total area sufficiently affected by alkali to prohibit plant growth probably would not exceed 300 acres.

Although these analyses indicate the presence of excessive quantities of injurious salts, the areas so affected were so few and of such small extent that the construction of a special alkali map for the area was not deemed advisable.

Chemical analyses of alkali soils.

Constituent	No. 13387, Subsoil of 13386, 10 to 36 Inches—Per Cent	No. 13388, Subsoil of 13386, 16 to 60 Inches—Per Cent	No. 13390, Subsoil of 13389, 10 to 40 Inches—Per Cent	No. 13391, Subsoil of 13389, 40 to 60 Inches—Per Cent	No. 13392, Soil 0 to 10 Inches—Per Cent	No. 13393, Subsoil of 13392, 10 to 40 Inches—Per Cent	No. 13394, Subsoil of 1339, 40 to 60 Inches—Per Cent
Ions:							
Calcium—Ca	1.95	0.62	2.14	1.21	......	0.52	
Magnesium—Mg	2.21	4.96	......	3.12	1.39	1.31	4.31
Sodium—Na	23.47	17.36	24.64	24.78	27.33	27.71	18.10
Potassium—K	2.43	6.61	5.00	1.04	1.78	1.05	7.33
Sulphuric acid—SO_4	45.82	45.45	42.15	54.77	38.41	50.98	29.75
Bicarbonic acid—HCO_3	24.12	23.00	26.07	12.65	28.71	12.43	36.63
Chlorine—Cl	......	......	......	2.43			
Carbonic acid—CO_3	......	......	......	......	2.38	......	3.88
Conventional combinations:							
Calcium sulphate—$CaSO_4$	6.42	2.07	6.79	4.15	......	1.96	
Magnesium sulphate—$MgSO_4$	10.62	21.17	......	15.57	7.33	6.54	22.31
Sodium sulphate—Na_2SO_4	48.66	36.58	55.35	37.44	48.32	65.60	17.60
Sodium bicarbonate—$NaHCO_3$	27.88	20.24	24.64	14.71	39.60	23.16	45.49
Potassium bicarbonate—$KHCO_3$	6.42	16.94	13.22	2.94	......	2.74	5.58
Sodium chloride—NaCl	......	......	......	5.19			
Sodium carbonate—Na_2CO_3	......	......	......	......	1.78		
Potassium carbonate—K_2CO_3	......	......	......	......	2.97	......	9.02
Per cent soluble	.45	.48	.28	.58	.51	.77	.23

AGRICULTURAL METHODS.

Since the beginning of agriculture in the area the principal crops have been wheat, flax, oats and barley, and as all of these, excepting flax, are sown early in the spring, the short period between the thawing of the soil and the time for seeding makes it necessary to do much of the plowing in the fall. In the spring it is customary to go over the ground with a disk and a smoothing harrow, after which the field is seeded with a press or shoe drill. Threshing is done almost entirely from the field, the grain being at once delivered at the elevator, or, in some cases, held on the farm to await shipment later.

As yet no systematic rotation of crops has been established. One of the best rotations, according to some of the most progressive farmers, is wheat two years, followed by barley, flax, rye and oats.

During the last three years winter rye has been grown by some with much success, the practice being to drill it into the flax or oat stubble in the fall without replowing, or into wheat stubble where the ground was prepared late the spring preceding. Thus the young grain during the winter receives the protection afforded by the snow, which, lodging in the stubble, is not blown away. By this practice larger yields are obtained than from the spring seed-

ings and the crop is harvested in time to permit of summer plowing, thus eliminating the loss occasioned by an idle field during the entire season.

Too little attention is given to the manurial requirements of the land, and the injurious practice of growing wheat after wheat without returning anything to the soil is plainly noticeable on some of the older fields in the area. During the first few years after breaking the rich prairie sod the natural store of decaying organic matter is ample for crop production, but as cultivation continues and this humus is removed something must be added to take its place. This may not now appear essential, for the country is yet new and much of the soil still retains its original productive power, but the experience of the past has taught the wisdom of husbanding the resources of the soil rather than restoring them after it has deteriorated. The best and cheapest fertilizer for maintaining the productiveness of the soils of this area is well-rotted barnyard manure. Especially is this needed on some of the lighter soils, from which much of the organic matter has already disappeared. Care should be taken, however, to have the manure decomposed, lest the coarse litter make the soil too loose to retain sufficient moisture during periods of excessive drought.

AGRICULTURAL CONDITIONS.

The interests of Griggs and Foster counties are distinctly and exclusively agricultural. From one end of the area to the other, a distance of sixty miles, the energies of the people are directed toward the production of small grains. Except among the hills along the James river and the region south and west of Carrington, where settlement has been more recent, the farms are characterized by modern dwellings and large, commodious barns. Public roads have been laid out around every section in the area, and during the last few years considerable attention has been given to their improvement. The work horses are large and serviceable, and the farm machinery of the latest improved type. Improved breeds of cattle have been introduced, and on every hand are evidences of industry and thrift.

The prosperity of the region is strikingly shown by the rapid increase in the value of the lands. Ten years ago, in the vicinity of Cooperstown, unbroken prairie land could be bought at from \$5 to \$8 an acre, and improved farm land at from \$10 to \$12 an

acre. Now what little remains of the unbroken prairie sells for from $15 to $26 an acre, while improved lands command from $25 to $40 an acre. While in Foster county land values have steadily increased, they have not yet quite reached those in the eastern part of the area. In Foster county, within the limits of the area mapped, are 14,000 acres held by the state as school land, of which the average price is $11.50 an acre. Improved lands in Foster county are valued at from $20 to $30 an acre.

Only a small proportion of the land is occupied by tenants, who, as a rule, are intelligent and industrious farmers. According to the census of 1900, 73 per cent of the farms in Griggs county and 77.5 per cent of the farms in Foster county are operated by the owners. Since then, it is generally conceded, the tenant class has been getting smaller, due mainly to the fact that many of this class are acquiring farms of their own. The farms are rented on what is known as the crop-payment plan, by which the owner, furnishing one-half the seed and paying one-half the thrashing bill, receives one-half of the crop, or, furnishing nothing but the land, receives one-fourth of the grain delivered at the elevator.

Although there is a tendency toward smaller farms and better cultivation, there are still a few large holdings in the area. One of these near Bordulac is said to contain 16,000 acres, of which 10,000 acres are in a fair state of cultivation. There are many farms of from 600 to 2,000 acres. The census of 1900 gives the average size farm for Griggs and Foster counties at 427.6 and 437.9 acres, respectively.

The chief problem confronting the farmers of the area is that of securing efficient labor during the busy season of the year. Even the smaller farmers at such time are compelled to hire at least one man. Usually the wage for harvest hands ranges from $1.75 to $2.75 a day and board. While the hired laborers at this season are mostly of the transient class, they are more efficient than were those with whom the farmer dealt ten years ago. Only a few of the wealthier farmers are obliged to hire help the year round. These pay on an average about $20 a month and board. The greater number hire on what is known as the eight months' plan, from April 1 to December 1, paying from $20 to $30 a month and board. Many of this class of laborers soon acquire homes in the locality where they work.

Until recently all of the hay has been obtained from the wild grasses of the prairie and the coarse material of the sloughs. While the hay thus secured is nutritious, it does not equal that obtained from the meadows of tame grasses, and as nearly all the prairies are now broken up and the weeds are crowding out the wild hay in the sloughs the cultivated grasses are being slowly introduced to take its place.

Since the drought of the early eighties the area has been comparatively free from the ravages of pests which have damaged the crops in other regions. In 1904, however, the black stem rust appeared, which caused an estimated loss in Foster county of at least 15 per cent in the common varieties of spring wheat grown, and in Griggs county the loss in yield of these varieties was variously estimated from 25 to 50 per cent of the entire crop. Though the disease may not occur again in several years, this experience should teach the farmer to be on the alert to adopt a practice which, in case it should retürn, will prevent serious loss. The black stem rust* of wheat may exist in two stages. The first, known as the red rust stage, causes little if any damage to the crops. The second stage, known as the black rust, causes the shrinkage of the grain, and hence the damage. It is sometimes possible by careful cultivation and the selection of the early varieties for seed to have the grain ripen before the worst attack of the black rust stage is encountered. It has been found that the durum varieties are without doubt the most rust-resistant wheats now grown. Among these varieties the Iumillo, Velvet Don and Arnautka are said to take the lead. Although the price ranges from 12 to 15 per cent below that of the common varieties, the fact that the average yield is 20 per cent more makes them valuable varieties to grow.

From the beginning flax has been considered one of the most profitable crops grown in the area. This is due in part to the fact that a good crop can be secured on the newly broken prairie with much less tillage than the other crops demand. It is, however, so exhausting to the soil that it is never wise to attempt to grow two crops in succession on the same piece of land, but they should be placed as far apart as possible in the rotation practiced on the farm. During the last few years this practice has been necessitated by the appearance of a disease known as flax wilt, which materially affects the yield of the crop if grown on the same field two or more years in succession. For this reason, and because so much

of the original prairie is already broken up, leaving no new land available for flax, the acreage of the crop during the last few years has been materially decreased.

In the greater part of the area only the seed of the plant is utilized. However, tow mills have been established at Cooperstown and at Kensal for working up the straw into upholstering material; but the price paid for straw—$2 per ton—is so small that only the near-by farmers find it profitable to deliver it to the mill.

All through the area there is an apparent lack of appreciation of the adaptation of soils to crops, and in the past the economy of the farm has been characterized by the struggle to cultivate the greatest acreage of grain without regard to the quality of the land. Timothy, brome grass, alfalfa and red clover all do well, though as yet little experience has been had in their cultivation. More live stock should be raised and more alfalfa grown. The Marshall silt loam, where good subdrainage can be had, is well adapted to the growing of alfalfa. Corn, while not always a success, is succeeding better every year, and it is thought that within a few years, as a result of the work of acclimation, this crop can be grown with a fair degree of success. During the past year a number of the more hardy fruit trees have been introduced, but the growing of orchard fruits is still in the experimental stage.

Excepting the western part of Griggs and the eastern part of Foster county, the transportation facilities of the area are good. Carrington, the principal shipping point of the western part of the area, is located at the junction of the Devils Lake and Sykeston branches of the Northern Pacific Railway, connection being made with the main line at Jamestown. Through Carrington also passes the main line of the Minneapolis, St. Paul & Sault Ste. Marie Railway, forming a direct route to both the northwest and the cities of the east. The Coperstown branch, leaving the main line of the Northern Pacific at Sanborn and passing north through Cooperstown, gives excellent transportation facilities to the eastern part of the area. These railway lines place the area within easy reach of the great grain markets, of Minneapolis, St. Paul, Superior and Duluth.

A CHEMICAL CONSIDERATION OF THE SOILS OF THE COOPERSTOWN-CARRINGTON AREA.

By John T. Weaver.

This area includes two tiers of townships in the southern part of Griggs and Foster counties, and consists of townships 145 and 146, north, and ranges 58, 59 60, 61, 62, 63, 64, 65, 66, 67 west. The soils of this region are of glacial origin, in other words they were once rock, and have been ground to powder by glacial action, by glacial action being meant all the complex series of processes by which the great continental ice sheet, during the time known as the glacial period, transported and ground up the soils now covering the surface of many of the northern states. The soils are therefore the result of disintegration rather than the decomposition of rocks. However, the mere grinding to powder of rock materials will not make a fertile soil. Such factors as weathering, moisture, micro-organisms, aeration and organic matter greatly affect the agricultural value of soils. And it is because these may to a considerable extent be controlled by the farmer that it is of interest to him to make a geological and chemical study of the soil.

From what has been said it will be clear that the nature and chemical composition of the original rocks will have a close bearing on the agricultural value of the resulting soils. In various parts of this area one may pick up fragmentary rocks which differ considerably in appearance and composition. It is on evidence of this nature that we must base our conclusions as to what the original material was from which the soils were formed.

Following are some of the more common rocks and minerals found in this area: First, it may be well to explain that a rock may be composed of one mineral or of a combination of minerals. Minerals are of such definite composition as to admit of a chemical formula.

Granite is a very common rock. It is composed of the minerals mica, quartz and feldspar. When granite rocks are disintegrated

and subjected to the natural agencies of decay they generally yield a fertile soil.

Quarts in the pure state is the oxide of silicon. It is frequently seen almost pure, as white sand.

Feldspar is composed of silicia, aluminum and potassium, sodium or calcium. The potassium or potash feldspars are very valuable as soil producers, as they yield considerable potash. Either sodium or calcium may replace the potassium, and when this is the case the soils are not usually as fertile.

Mica is more commonly known as isinglass, and while it is not easily detected by the average person yet it is quite abundant. The ease with which some rocks split into thin slabs is due to the presence of mica. It contains magnesium, iron, calcium, manganese and silicia.

Horneblende rocks are found frequently in this area. They are generally black or dark green, and while they are not so valuable as soil formers yet they are never responsible for "alkali soils" which are so troublesome in some localities. Horneblende contains magnesium, calcium, iron, manganese and silica.

Limestone rocks have played an important part in the formation of the soils of this area. Pure limestone is calcium carbonate, though calcium carbonate and magnesium carbonate are often associated together. This mineral and also gypsum (calcium sulphate), will be further treated under the head of calcium.

The above will give the reader a general idea of the origin of the soils and the sources of plant food contained therein. When a chemical analysis is made of a plant it is found to be composed of sixteen elements, with sometimes traces of one or two more. Only twelve of the more important ones will be treated in this article, the others being non-essential or of no practical importance to the farmer.

Aluminum is a white metal when pure:. It is the chief constituent in clays and shales. It is not essential to plant growth.

Silicon is one of the most abundant elements forming the earth's crust. Combined with oxygen it forms our "white sand." It is found in large quantities in the ash of plants. For some time it was considered the element which gave strength and stiffness to straw. At present this quality is doubted and its value to agricultural plants is not definitely known.

Iron in very small quantities is essential to plant development. It is generally well distributed in nature in combination with oxygen. In the area under consideration there is abundance of iron in the soil. The red or rusty color so frequently seen in gravelly or sandy places is due to the presence of the oxides of iron, or iron rust. Agricultural plants fail to develop and turn pale, losing all their chlorophill, in the absence of this element. This is one reason why housewives sometimes place rusty nails in their flower pots.

Manganese is closely related to iron, but is not necessary for plant life. It is found in plants in small amounts, but cannot take the place of iron as plant food as is sometimes supposed.

Chlorine is an essential food of plants, and is found widely distributed in nature, combined with sodium in the form of common salt. Plants will develop normally until the blossoming period without chlorine; then, however, it seems necessary to have chlorine along with other elements for the development of fruit and seed.

Sulphur is required in small amounts by all plants. It is most probably taken up by the plants in the form of calcium sulphate or gypsum. The characteristic flavor of onions, mustard, horseradish and other similar vegetables, is due to the presence of sulphur in the volatile oils. Sulphur is contained in the soils of this area in two forms. It is quite well distributed combined with iron as a sulphide. In this form it is found near the surface in the light soils, and six to ten feet or more below the surface in the heavy types. It occurs as a bright yellow crystal and is often mistaken for gold, hence its common name of "fool's gold." As a sulphide it is not available for plant food, but under favorable conditions it may in time be converted into the more desirable soluble forms. In the form of calcium sulphate or gypsum sulphur exists on this area in sufficient quantity to produce grain crops for years to come. It may frequently be seen in the soil as small, clear, shining crystals, and near wet places is often found in noticeable quantity as dirty grey crystals nearly as large as pin heads. This is the form in which the plants absorb it. Little is known of the function of sulphur in plants. Albuminoids, of which it is an ingredient, can be formed only in the presence of sulphates.

Phosphorous is one of the important elements in plant culture. It is used by the plant in the form of phosphoric acid. It seems to aid in transporting the proteids through the cell walls. An important point to the farmer who uses fertilizers is that farm crops

require from 50 to 75 per cent of the total amount of phosphoric acid before the blossoming period. Most of the phosphorus is stored in the seed, and this is one reason why farms which have been cropped continuously with wheat or other small grains, become deficient in available phosphoric acid. This is readily explained when it is considered that twenty-five pounds of phosphoric acid may be removed from an acre yielding forty bushels of wheat. An imperfect supply of this substance results in a yeld of light weight grains. This substance is one that is likely to become deficient in the soil. It is quite expensive as a fertilizer, and is not easily managed when so used. It should be understood that most soils contain a sufficient supply of phosphoric acid, but that it is combined with other elements, or "locked up" as it were by nature in such a way that plants cannot use it. Good cultivation, manuring and liming where necessary are the best methods known for "freeing" the phosphorus and making it available for plants.

Calcium is well distributed through this area. The white limy character of the soil in many places, especially in the lighter types, is due to the presence of calcium salts. It is chiefly present in the form of calcium carbonate or powdered limestone. Calcium is well known to the public when combined with oxygen in the form of lime. What was said of calcium as calcium sulphate under the head of sulphur is applicable here. Calcium is directly necessary for the formation of cell tissue. Experiments have been performed which show that calcium compounds are necessary for the conversion of starch into cellulose. Calcium is widely used as a fertilizer Calcium phosphate is the chief constituent of some fertilizers. Ground bone contains considerable calcium phosphate but is rather slow in its action as a fertilizer.

Calcium is not only an essential plant food but it is also very beneficial to the soil. It acts both chemically and physically. Chemically it aids in freeing and "unlocking" potassium and phosphorus so that plants can use them. It unites with the organic acids and thus prevents the souring of soils. It also aids in nitrification. Physically it tends to bind light soils and to floculate the heavy clay soils, thereby increasing capillarity and destroying the sticky and adhesive properties of clays. In contrast with phosphorous, only about two pounds would be removed from an acre of heavy wheat.

Magnesium is necessary for the production of fertile seed. Small quantities, however, are sufficient for the production of heavy crops. Our common beans contain only about one-fourth of 1 per cent of magnesium. It seems to be necessary at the seat of operations where inorganic material is converted into organic. The abundance of magnesium in this area is such that it need not be considered in the question of fertilizers. When combined with oxygen it is known as magnesia. In combination with chlorine it is somewhat injurious to crops, but when associated with calcium as carbonate it is beneficial. As a sulphate (epsom salts) it is sometimes found in the water of deep wells of this area.

Potassium is necessary for plant growth, and like phosphoric acid and nitrogen it is likely to become deficient in soils. Without potassium plants seem to be unable to form starch granules, and while a plant may live for a considerable time yet it is unable to add to its total weight when deprived of this element. It is used by the plant in its early stages of growth, hence when used as a fertilizer it should be applied in time to be of the most benefit to the growing plants.

Potassium unites with organic acids to give those characteristic flavors common to many plants: thus, potassium oxalate in sorrel, potassium bitartrate in the grape, and potassium malate in rhubarb. It must not be understood, however, that the plant takes the above compounds as such from the soil. Potassium chloride is probably the most favorable form as a food supply, though the phosphate or sulphate and other salts may be used. Most of the potassium is stored in the straw and leaves of our farm grains. Only about one-fourth is lost by selling the grain, while the remaining three-fourths may be retained on the farm if proper methods are used. But by burning the straw in large heaps it is almost a total loss unless the ash is carefully used as a fertilizer. The better method is to cause the straw to rot and spread as manure. From six to fifteen pounds of potash (potassium) may be removed from an acre by selling the grain, while from twenty-five to sixty pounds will remain in the straw. Potash may be present in the soil in considerable quantity and yet be in such combination that the plants cannot use it and starve for the want of it. The method described under phosphorus for "freeing" that element also apply in the case of potassium.

Soils generally contain from 3,000 to 12,000 pounds of potassium per acre in the first foot. So the advisability is readily seen of using the best methods for making these elements in the soil available for plants rather than use expensive fertilizers. At least it should be first demonstrated that fertilizers are necessary and that the returns are more than sufficient to cover the extra expense before large sums of money are expended in commercial fertilizers.

Sodium is found in considerable amounts in all our field crops. Whether it is essential to plant growth is at present an open question. It is a fact, however, that sodium is never totally absent from plants, and that if indispensable only very small amounts are requisite. The foliage and succulent portions of plants must contain considerable amounts of this element that are unnecessary.

Sodium is very closely related to potassium, but cannot totally take the place of the latter in plants. It is not used directly as a fertilizer. An excess of sodium salts is injurious to crops. They are included in the alkali group. Table salt is a compound of sodium with chlorine, excessive amounts of which destroy the productive qualities of the soil. What the housewife uses for baking soda the farmer condemns as "black alkali." It is the most injurious salt in the alkali group. Fortunately this area does not in general contain any excessive amounts of alkali. It is true many of the well waters are salty, but these wells are generally quite deep and the salts are not likely to rise to the surface in sufficient amounts to seriously hamper agricultural pursuits. In the southwestern portion of this area there are some "alkali spots." The most of the land so affected lies with a gentle slope, affording good surface drainage. The writer believes that with good cultivation this land can be successfully tilled. One thing noticeable in these "alkali spots" is the lack of humus. If this land were plowed in narrow lands with the dead furrows open so as to assure the best surface drainage, and then plenty of well rotted manure applied, especially horse manure, it would greatly add to the productiveness of the soil. Not that the manure will "kill" the alkali, but in decomposing it yields organic acids which unite with the basic elements of the alkali and thus render it inactive. The manure also improves the tilth and texture of the soil, and by good cultivation more plant food is made available, with the result that the young crop shoots up and early protects the soil from evaporation, thus tending to avoid the concentration of the alkali.

Nitrogen is one of the essential elements of plant food. It is not so much an element of the soil as of the atmosphere. In other words it is a gas, and constitutes about three-fourths of the atmosphere. It is generally well known that plants cannot use the free nitrogen of the air, but must obtain it from the soil through their roots. Leguminous plants, such as the bean, pea and clover, have the power of increasing the supply of nitrogen in the soil. Quite a number of farmers have made some attempts at raising varieties of these plants in this area with varied success. One large farming company under the direction of the department of agriculture, is conducting a number of experiments with clover. Some plats were inoculated with "nitrogen bacteria," while others received the same cultivation but were not inoculated. So far as could be seen no advantage was gained by the inoculation. The fact that the writer visited these plats early in the season before harvest, and that it was the first year the experiments had been conducted, should be taken into consideration. It is generally considered, however, that these soils do not need to be inoculated.

When it is considered that all life is ultimately dependent upon the soil as its source of food—animals feed upon plants and plants alone have the power of transforming the lifeless inorganic material into vegetative tissue—it will be realized that a knowledge of the original rocks is important and interesting. Had the original rocks from which the soils of this area were formed been of some other material and composition the result might have been a barren soil. But nature was kind to this region and made such a distribution that the soil contains in goodly quantity all the elements necessary for plant growth. Yet not in such great abundance that the farmer need have no care for the future. With good methods of farming, aiming to conserve the fertility of the soil, this area will continue productive for a long time to come.

A PRELIMINARY REPORT ON THE SOILS OF RANSOM COUNTY.

BY JOHN T. WEAVER.

During the summer of 1906, a soil survey was made of Ransom county. The work was conducted by the Bureau of Soils of the department of agriculture in co-operation with the geological department of the State Agricultural College.

Such a survey is of especial interest and value to farmers and property owners of the area as it gives reliable information on the nature, value and productiveness of the soil. The Bureau of Soils is making a scientific study of the soils of the country, laying special emphasis also on the practical side of the question, while the Agricultural College investigates the soils of the state. It is only through such investigations that a thorough knowledge of soil and climatic conditions can be obtained, and such knowledge is necessary in order to introduce new cereals and grasses successfully and economically.

The field party aims to classify and map all types of soil comprising an area of ten acres or more. This requires considerable training and skill on the part of the surveyors. They further take cognizance of precipitation, methods pursued in agriculture, and the adaptability of crops to soil types. As every practical farmer knows, the subsoil as well as the top soil has a marked influence on the kind and quality of the grain or grass, which may be grown. In fact the first three feet of a soil must be examined in order to properly classify it. In making such a detailed study the surveyors use augers for penetrating the soil, and not only test the soil to a depth of three feet but also collect samples of each type. These samples are analyzed and the data compiled. Duplicates are preserved at the Bureau of Soils, Washington, D. C., and at the State Agricultural College.

The soils of Ransom county are the result of glacial action. It must not be inferred, however, that moraines and glacial deposits are a conspicuous feature of Ransom county landscapes; on the

contrary, large areas of comparatively level and fertile soil are to be found. Nature was kind to this area in distributing a soil which has a natural inherent fertility. To fully appreciate this the reader must consider the fact that over 80 per cent of the best wheat land of North America lies within the glacial belt. The waters of the great ice sheet assorted and deposited these soils in such proportions as to make them very valuable for agricultural pursuits.

Chemical analyses of these soils have not as yet been made, but the writer believes from his studies of the physical character that all the elements necessary for plant growth are present in sufficient quantity to insure good crops for years to come. Much of this land has been cultivated since the early settlement, and so far as the writer could learn no commercial fertilizers have been used. With good methods of cultivation it is not likely that the farmers will have to purchase any fertilizing products for generations to come.

It may be possible that such extensive wheat raising as is now practiced will have to be modified or more crop rotation introduced, but this should increase rather than decrease the income of the farmer. At the present time the greatest resource of the county lies in the wheat production. This is especially true of the central and western part of the county. The farms are generally large, and as labor is scarce and very expensive, little or no intensive farming is pursued. The farmers mostly have no by-products, the reason being possibly due to their prosperity. There are many farmers who have no source of income except the grain crop. This in itself proves the splendid fertility of the soil, for in many regions in other states were the farmer to depend upon wheat alone, he could not live in the luxury that many Ransom county farmers do. It is true that some farms are mortgaged, but this more often indicates prosperity than adverse circumstances, since the farmers realize the value and productiveness of the land and mortgage in order to increase their holdings.

All of the common small grains are raised in abundance. Wheat, oats and barley are raised for export. Speltz has proved itself to be a good yielder, but as yet it has not come into popular and general use with the farmers. Durum wheat is one of the best producers; the soil and climate seems to suit this cereal very well and in spite of the fact that the market price is somewhat below that of the fife and bluestem varieties it is profitably raised for shipping

purposes owing to the larger yield per acre. Flax is also raised to a considerable extent especially on the new land.

The native grasses are used largely for hay. Not much attention has been given to the raising of tame grasses. The writer noticed a small field of timothy which would produce a fair yield of first-class hay; probably one and one-half tons per acre. Red clover receives practically no attention. A small patch of about one acre in the northern part of the county showed that it might be grown with at least a fair degree of success. Alfalfa has not been given a sufficient trial to pronounce it either a failure or a success. It will live through winter and grow fairly well under somewhat adverse conditions and just what it would do under favorable conditions is hard to say as the writer was unable to get any very definite information on the subject.

The soils of the county are generally of a deep, rich black loam containing large amounts of humus and organic matter—excepting probably those of the Sheyenne delta and the Sand Prairie region which are considered elsewhere. Upon the major part of this area the type of soil is that known as Marshall loam. Excepting local spots, all the land in the county lying north of the Sheyenne river belongs to this type, and also a large tract exending south of Lisbon to the county line and west and northwest beyond Elliott to Fort Ransom.

The Bureau of Soils describes this type of soil as follows: "The soil is a dark brown loam, ten to twelve inches deep, resting on a lighter-colored loam or heavy loam. The deep subsoil consists of clay, sand, gravel and boulders mingled together in a disorderly mass. The type is derived from unstratified glacial drift. * * * The type occupies gentle undulating to rolling country and covers wide areas in the prairies of the northwest. * * * The soil is excellent for general farming purposes. Wheat, oats, corn, barley and flax are the principal crops." Root crops also do well in this soil; and stock raising is very profitable.

Stock raising is pursued to a very small extent. The reason apparently is that the expense of erecting buildings and the labor question makes it more profitable to raise wheat and the other cereals.

The writer cannot understand why more attempts are not made to raise small fruits. In different parts of the state many of the hardier varieties of fruit are raised to such an extent as to be a

(a) WATER POWER OF THE SHEYENNE RIVER, AT LISBON.

(b) FORT RANSOM, IN SHEYENNE VALLEY.

decided source of satisfaction and profit to both home and farm. Currants, gooseberries, strawberries, raspberries and some plums are a decided success. Those who have taken some care in the way of securing protection to the plants are proud of their success at raising raspberries, grapes, crabapples and many of the hardier varieties of apples.

All kinds of garden vegetables do remarkably well. There seems to be a prevailing opinion that small fruits do not do well so far north but the reason is most likely one of neglect. It seems the more easy and rapid method to make money out of extensive wheat fields and to buy the fruit.

The Sheyenne delta was formed at a time when what is known as the Red River valley was a large lake. The material was deposited in the quiet waters of Lake Agassiz by the Sheyenne river. It was, therefore, formed at a different time and under different conditions from the rest of Ransom county, and hence is of different material and naturally has a different agricultural bearing than the adjoining land. The eastern portion of Ransom county is embraced in the area of the delta. The western limit of the delta is traversed approximately by a line drawn from Milnor through Sheldon and northward to the Cass county boundary. Thus about 250 square miles of the delta plain is embraced within the county, and the area included in the soil survey.

The soil is lighter in character, and in some places has been piled up by the winds in the form of dunes. This sandy soil, where not too excessively light, is steadily increasing in value with improvement in farming methods. It does not yield wheat like the heavier types; yet as stock land it seems to be quite profitable. On account of its texture and soil moisture it is probably less valuable for wheat growing than for grass production. The soil is generally loose and free and the water table is only about four or five feet below the surface, and in wet seasons is even higher than this.

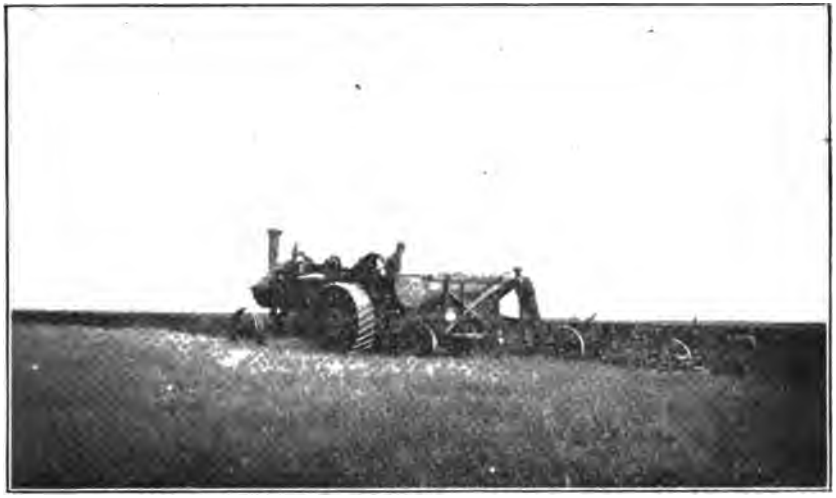
Grasses are naturally shallow feeders. They do not as a rule send their roots deeply into the soil. If the land were broken and seeded to some suitable grass this soil should make stock raising profitable. But much care is necessary in selecting the best kinds of grasses. There is probably no better way of learning this lesson than by practical tests. The native wild grasses seem to be too tough and wirey to produce the best results, still in some localities

there are large herds of cattle pasturing on the native grasses and apparently yielding profitable returns.

So far as the writer could learn, practically nothing has been done in the way of improving the grasses. The country is new and prosperity runs too high for experiment. The raising of alfalfa might well be considered. The soil and climatic conditions are in many ways suitable for this plant. Only a few attempts have been made to raise it, so far as the writer could learn, and in these cases the work was not managed in such a manner as to make the results obtained of any particular value. A thorough knowledge of the habit and requirements of the plant are essential before large crops can be secured. It should not be expected that alfalfa will yield as heavy crops here as in the warmer states. However, a light, porous soil with abundant moisture within four to six feet of the surface furnish ideal conditions for the growth of this crop, and further experimentation on these more sandy soils should yield some valuable results.

A tract embracing several thousand acres in the northwestern part of the county and west of the Sheyenne river is locally known as Sand Prairie. This tract of land was formed at a time when the waters of the great glacier made the Sheyenne a most formidable river. The course of the river was blocked at the bend at Fort Ransom by the great wall of ice of the great continental glacier, and the rush of waters had to find a course in a southwesterly direction toward the James river. Before a channel could be cut the water formed a large flood plain which has become popularly known as Sand Prairie.

The soil of this region may be roughly divided into two kinds: one a dark-colored to black loam underlaid with a heavier loam. It is similar in texture to the soil lying in the northern and central portion of the county and is well adapted to mixed farming. The second kind is characterized by a dark to black soil ranging from eight to twelve inches deep, and is underlaid by sand. Wells furnish abundant supplies of good water at depths ranging from six to twelve feet. General farming is largely practiced in this region. It is generally known that the water table is about six feet below the surface and the question has been raised whether or not this land would be adapted to the raising of alfalfa. It is not possible at the present time to give a definite answer. The plant has received little attention from the farmers in this locality and



(a) PLOWING BY STEAM.

(b) SAND DUNES OF THE SHEYENNE DELTA, SOUTH OF SHELDON.

its possibilities are not fully appreciated. It is true that this soil has many of the essential features of a good alfalfa producer, and it is also true that alfalfa is raised with good success in a latitude farther north than this.

The question of the adaptability of the Sand Prairie region to the growth of alfalfa was presented to one of the men in charge of crop experiments of this character at the State Agricultural College, and after describing the conditions he said that the description answered well for an ideal situation for the growth of alfalfa.

The belief seems to be common in many of the eastern states that "alkali" is present in most of the prairie lands of the northwest. And many intending purchasers of the western soils are skeptical until assured that the crops are not injured by this agent.

Ransom county soils may be said to be practically free from alkali. It is found in a few very small and isolated spots throughout the area. These are always low places where drainage is poor, and in dry weather can usually be detected by the appearance of the white soil on the surface of the ground. In no part of the area did the writer notice any ill effects upon cultivated crops due to the presence of alkaline salts.

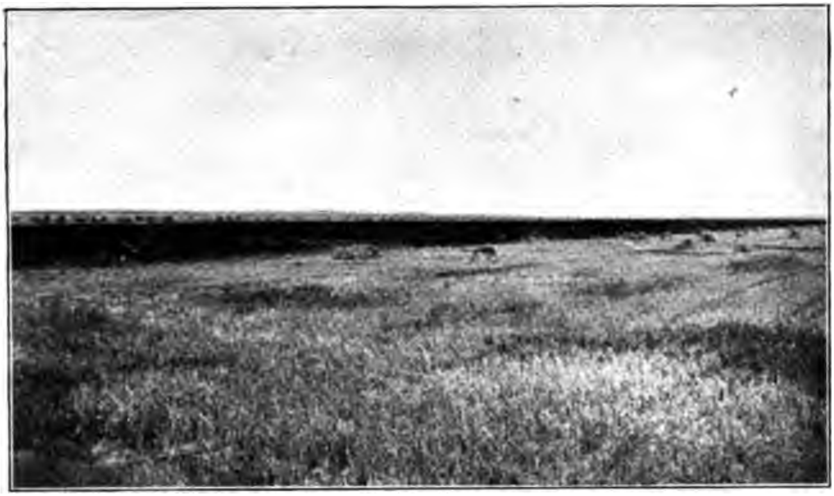
A PRELIMINARY REPORT ON THE SOILS OF WILLIAMS COUNTY.

BY REX E. WILLARD.

The soil survey of the Williston area was made possible by the co-operation of the United States Soil Survey and the people of Williams county with the State Survey of the Agricultural College. It is not the purpose of this paper to make a technical report of the work of the survey but rather a report of general information and interest to the agricultural citizen. A detailed report with the soil map by Thomas D. Rice will appear from the United States Department of Agriculture in September, 1907. This report will also appear in the fourth biennial report of the Agricultural College Survey of North Dakota.

The area, consisting of sixteen and one-half townships, is located mainly north of the city of Williston. The northern boundary of the area is the township line passing east and west a short distance south of Freeman's ranch in the Little Muddy valley. It is the northern line of township 157 north. The eastern boundary passes just east of the village of Wheelock. It is the eastern line of range 96 west. The township in which Williston is located and the township east of Williston were the only ones surveyed in township 154 north. The area covers the two principal kinds of land in the county, i. e., upland and lowland. The soils of the Missouri bottom are found in the townships in the vicinity of Williston. The reworked glacial soils are found in the Little Muddy valley, while the upland soils are found to the east and west of the Little Muddy. By glacial soils is meant the drift debris left by the glacier when it melted. The area was chosen to cover as many kinds of soil as possible during one season's work.

The soils of the lowland are distinctly different from those of the upland. The lowland soils are reworked drift material left by the glacier. These occur along the Missouri river as sands and clays; also they occur in the Little Muddy valley. These soils are not uniform in texture or deposit. A type that from its location might be



(a) HARVEST FIELD IN NORTHERN WILLIAMS COUNTY.

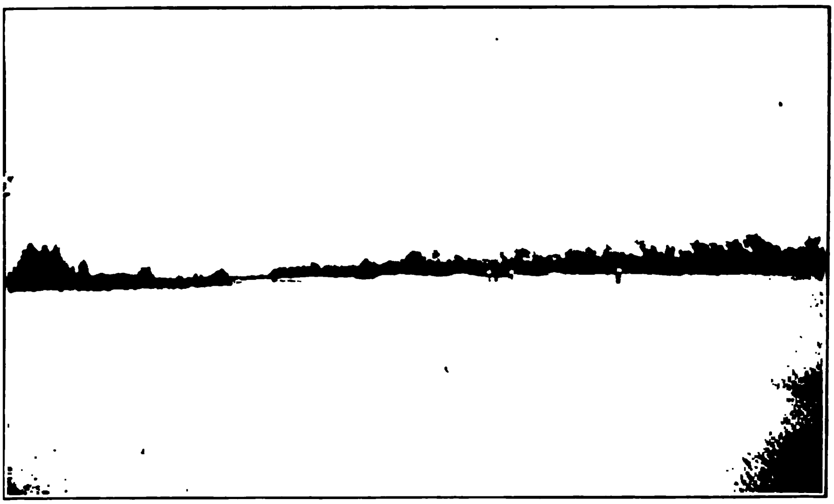
About 8 miles south of Crosby.

(b) SLOUGH OR SMALL LAKE IN MORAINIC HILL DISTRICT OF WILLIAMS COUNTY.

South of Vandalia. The lake is slowly filling with the accumulated vegetable matter. It will in time become a hay meadow. Muskrat mound in center. Birds at water edge in foreground.

(a) SUN CRACKS IN MUD OF MISSOURI BOTTOMS.

Watch in center of foreground shows width of cracks. Near Bell's ferry. Williston in distance at left.



(b) SAND OF MISSOURI RIVER BOTTOMS.

One mile above Bell's ferry. Sand blown into dunes.

(a) DRIFT BOULDER IN HOLLOW.

Known as a "buffalo boulder," from the supposed habit of these animals of rubbing their bodies upon the rock, and thus by tramping wearing a hollow about the stone. The rolling prairie of Williston county, with native vegetation. Harvest field in distance.

(b) STONY LOAM, IN NORTHERN PART OF WILLISTON SOIL AREA.

expected to be a clay or heavy soil for instance, will be very sandy, and vice versa. Such irregular deposition shows a great variation in the course and volume of the old glacial stream.

The soils of the upland occupy a greater area than those of the lowland. These are much more uniform in location and texture than the channel soils. There sometimes occurs an area as large as half a township of the great loam type of the upland, without scarcely any variation. (See Plate XXI A.) There occasionally occur sloughs or small lakes (Plate XXI B) in the loam area but they occur much more frequently in the stony loam or morainic hill region. The loam is the greatest and best soil type of the area.

The soils of the channels may be conveniently divided into two classes, i. e., heavy bottoms and benches, consisting of sand and gravel. It is evident that during the closing stages of the glacial epoch there was a very great amount of water in these channels. The melting ice not only produced water but dropped any rocks and soil debris that it contained. The heavier material was deposited where the water moved the most slowly. Plate XXII A shows a deposit of mud near the Missouri river. The sun has baked the deposit so that large crevasses have been formed. Plate XXII B shows sand dunes only a few rods distanct, that portion in the foreground being sand. The rocks and coarser materials were left where the water was shallow. Thus we have the rocks along the borders of the streams and the gravels and sandy soils on benches or shoulders in the bottoms. This fact is illustrated at the present time by the variable deposits of the Missouri river where it changes its course.

Generally there is a considerable amount of organic matter in the channel soils. There is little doubt but that there is sufficient humus to produce any crop that will grow in this climate. There is some evidence of alkali in the valley of the Little Muddy, but with proper drainage under the irrigation project little injury to the crops will be noticed.

The soils of the uplands occupy at least three-fifths of the whole area. There are two general types of the upland prairie, viz., loam and stony loam. These are intermingled sometimes definitely and at other times very obscurely.

There are many dry coulees and channels on the upland which do not carry water even in the wettest season of the year. These were formed during the recession and melting of the ice sheet where

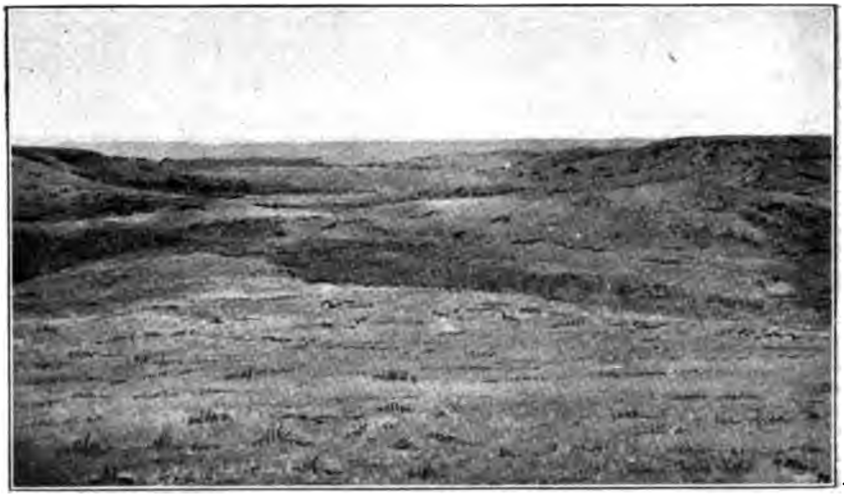
vast amounts of water found its way to the sea by the channels of the least resistance. Along these channels occur many rocks which were deposited with the debris of the glacier. The water eroded away the lighter soil and left the rocks piled sometimes one upon another along the borders or in the bottom of the channels. This accounts in many instances for the occurrence of stones along the stream courses.

The loam soil has the greatest acreage of any type of the area and is the best soil for agricultural purposes. The largest continuous areas of the loam type are found in townships 156 and 157 of ranges 97 and 98 west, a few miles north of Wheelock; in the vicinity of Epping, in townships 155 and 156 of range 99 west; northwest of Spring Brook in township 100 of range 156 west. It occurs everywhere on the upland except where the stones are numerous. The soil or upper portion of the type is from eight to ten inches in depth. It is of a dark color and contains considerable organic matter. The subsoil is heavier in texture than the soil and is quite impervious to water. This last characteristic makes the type particularly adapted for crop production in a semi-arid region. It is upon this soil that Williams county depends for its best crops.

The stony loam covers an area perhaps one-fifth as large as the loam. The soil and subsoil of this type is not essentially different from the loam type except that the soil is a little more shallow and contains less organic matter. As the term stony loam indicates, there are stones in great abundance in the type. The stones vary in size from small pebbles to large cobblestones. They are entirely of glacial origin and occur along the coulees and glacial channels in the greatest abundance, but are not infrequently found scattered over the prairie both singly (Plate XXIII A) and in areas of a few acres each (Plate XXIII B). Plate XXIV A shows the type as it occurs in a glacial channel.

As before indicated the stony loam occurs along the stream courses principally but in nearly all of the worst hilly country are found stones in great abundance. This type is particularly characteristic of the morainic hills (see Geology of the Tower Quadrangle), which occur over a considerable portion of the Williston area. Good illustrations of these hills are seen to the east and west of the Little Muddy valley.

There is a very great variety in the soils of the area. There is therefore a great opportunity for variety in crop production. The heavier soils are adapted to the production of garden products,



(a) GLACIAL CHANNEL, WITH LARGE NUMBER OF STONES, WILLIAMS COUNTY.

(b) THRESHING OUTFIT, IN LITTLE MUDDY VALLEY.

(a) BUTTES SOUTH OF WILLISTON.

Missouri river and flood plain in distance. The sides of the buttes are naked. Hard layers of sandstone are exposed near the tops.

(b) THE ROLLING PRAIRIE COUNTRY NORTH OF WILLISTON.

The circle of stones in foreground marks the location of an Indian tepee.

(a) FREEMAN'S RANCH, IN LITTLE MUDDY VALLEY.

This is the characteristic type of ranch barns and barnyards—of logs, poorly built, and covered with a thatch roof of hay or straw.

(b) THE SOIL SURVEY PARTY IN CAMP.

The location here shown is about 14 miles north of Williston. Little Muddy valley in distance.

where there is sufficient water supply, and the lighter or more sandy soils are adapted to the production of small grains.

Thus far there has been scarcely any production of garden crops. The season is generally long enough for the maturing of crops of this nature, but the settlers generally have devoted their attention to the raising of small grains rather than to the cultivation of these crops.

At the present time there is produced some flax, wheat, oats and barley. Flax is seeded generally on newly broken sod. Eight bushels is about an average per acre for this crop. Wheat is raised to some extent. Oats and barley are raised entirely for feeding purposes.

The fallowing and spring plowing are many times not well done. Shallow plowing is frequently seen. Weeds are not uprooted and as a result these get an early start against the grain. These methods, with lack of harrowing, are the cause, to a large extent, of the appearance of the mustard and other weeds of the region. Deep and thorough plowing and plenteous harrowing will be beneficial. In a region of sandy soil these methods are particularly good as it is desired to conserve as much moisture as possible. This applies directly to the loam type of the area.

Together with the grains mentioned may be raised other products such as alfalfa and timothy hay. A few fields of these crops are under cultivation at the present time and no doubt is entertained but that they may be successfully raised on the irrigated lands of the area.

There are not many occupations to which the stony loam of the area can profitably be put. It is a loss of time and labor to break this prairie sod which grows buffalo grass and others so plentifully. The soil is too dry to produce grain and too rough to be cultivated. Grazing may be carried on with profit where large tracts are available. Cattle, horses and sheep may graze here among the rocks and hills where cultivation is not only impracticable but in many cases impossible.

During the season of 1906 two soil surveys were made in North Dakota in co-operation with the United States bureau of soils. This co-operation was made possible through the assistance and support of the citizens located in the areas surveyed, both by personal and financial aid. It is desired to convey proper appreciation of the support of the citizens of Williston and vicinity in furthering the work of the soil survey.

NATIVE PLANTS OF WILLIAMS COUNTY.

A PRELIMINARY REPORT OF THE BIOLOGICAL DIVISION OF THE SOIL SURVEY OF WILLIAMS COUNTY, NORTH DAKOTA,

By W. B. Bell, Ph. D.

The addition of the biological division to the soil survey of North Dakota was made possible during the past summer through the co-operation of the department of biology of the Agricultural College with the Agricultural College Soil Survey.

This report is intended to present only a few subjects of general interest, leaving the more detailed account until time shall have been given to work over the data and materials gathered with all possible care, when the results will be published in connection with the reports and bulletins of the two departments.

Previous to this time work along this line had been done in several localities throughout the state by Prof. H. L. Bolley, of the Agricultural College, and Mr. L. R. Waldron, now director of the sub-experiment farm at Dickinson, N. D., but owing to limited financial support the work was accomplished at considerable personal sacrifice. The uniting of this work with the soil survey makes a distinct advance by providing additional facilities for carrying forward this branch of research.

In the state of North Dakota where agricultural interests are paramount and lie at the foundation of all her splendid industrial possibilities, no defense is needed for adding to the study of the soils an investigation of the native plant life which flourishes upon them. The plants which have succeeded in maintaining themselves upon the soils under natural conditions throughout the centuries past afford a crucial test of the soil, and a thorough knowledge of them gives a sound basis for judgment regarding the value and fitness of the land.

Objects of the Survey.—The primary objects of the survey may be stated briefly as follows: First, to determine what cultivated crops are adapted to the soil and climatic conditions prevalent in

this region. No more important problem confronts the agriculturist than to ascertain what crops he should cultivate in order to secure the largest possible returns in proportion to the time, labor and money expended. The best known index for the solution of this ever-pressing question lies ready at hand in the native plants themselves. Through the long periods of time which have elapsed the ancestors of the present plants have contended with the prevailing conditions which surrounded them. The plants which were unable to cope with these conditions have been weeded out and leave in the rocks only enough of their remains to tell of their failure. The plants which were able to adapt themselves to their environment and to thrive in the midst of their surroundings so as to propagate after their kind have left written deep in the structure and distribution of their descendants, the present flora, the record of their struggles and final triumph. This record may be read by the thoughtful, observant man and be interpreted to his profit, since it points out the characteristics which should be possessed by the plants that he cultivates, in order to secure the full measure of fruitfulness from the soil.

Second: To investigate the relation of the soil and moisture to plant life. The gathering of all possible data upon this subject is of the greatest importance at this time when the bureau of soils at Washington and various experiment stations are endeavoring to ascertain what are the controlling factors in crop production. The trend of opinion today is that the proportion of chemical elements in the soil is of far less importance than the moisture content of the soil together with the substances dissolved therein, known as the soil solution. The observations made during the past summer in this survey strongly enforce this opinion.

Third: To discover native plants which are worthy of preservation and cultivation. The importance of selecting from the native flora those grasses and other plants which possess food or forage value for improvement by cultivation cannot be emphasized too strongly. Thousands of dollars are being practically thrown away annually in North Dakota in vain attempts to introduce crops from other localities where conditions are different. These attempts are frequently doomed from the start because the plants are not adapted to the conditions, and failure and disappointment are the natural results. This waste is going on while at our very doors are plants which are unsurpassed for nutritious qualities, perfectly adapted

and hardy under our soil and climatic conditions which would, perhaps, give a bounteous yield in response to proper cultivation. It is of the utmost importance that this matter be given immediate attention before our valuable heritage of native plants shall be lost forever to civilization through their ruthless and careless destruction while the land is being broken up for cultivation by the rapidly increasing host of settlers who are coming to make homes and develop the resources of North Dakota. The eastern portions of our country have incurred serious loss which can never be retrieved through the destruction of their valuable native flora, and the west may well profit by this experience.

Fourth: To ascertain the location and distribution of noxious weeds. Weeds are always a trouble and menace to the farmer because of the labor involved in their suppression and the reduction in value of his products due to the presence therein of the seeds of injurious weeds. Moreover forms which are poisonous to man and beast should be located in order that they may be eradicated or guarded against.

The easiest time to keep these pests under control is while the country is new before any troublesome forms have had an opportunity to gain a secure foothold. It is a temptation to feel that while the land is new the weeds will not bother much. This leads one to adopt lax methods of cultivation until the weeds become numerous and widespread and have seeded the land so thoroughly that their control becomes a matter of great labor and expense if not an absolute impossibility. The annual loss therefrom also constitutes a continuous drain upon the resources of the land and reduces seriously the profits of the owners.

Fifth: To contribute materials and sound data to the rapidly increasing sum of accurate scientific knowledge of the flora of North Dakota. The well-known contributions which pure biologic science has made to human welfare renders it superfluous to dwell at length upon the importance of this phase of the work.

Other objects might be enumerated, but the above will serve to give a conception of the principal purposes of this North Dakota Biological Survey.

Methods of Procedure.—Careful collections were made of all plants which were found within the area during the season of survey. Many duplicates of all forms collected were made whenever possible. These materials were carefully pressed, dried and conveyed

(a) A CLAIM SHACK IN PROCESS OF CONSTRUCTION.

This is where the "price of raw materials" does not count. The house is already occupied, though the sod "shingles" have not all been placed upon the roof, and the outer wall has not been completed. The prairie surrounding is the characteristic landscape of a large part of Williams county, and shows some of the native plants.

(b) HABITATION NOW OCCUPIED, ON THE MISSOURI RIVER BOTTOMS.

The vegetation is that which abounds on these flats. Some large trees, with a dense undergrowth of perennial and annual plants. Grapes, hops, cherries, plums and gooseberries grow naturally here, a suggestion of what these lands would do under cultivation.

to the herbarium of the Agricultural College where they are kept for detailed study. A record was kept of the exact quarter section from which each plant was collected, together with notes upon the lay of the land, soil and moisture conditions, whether the land was broken or unbroken and whether the plants were native or introduced. Record was also made of the distribution of the various plants and collections were made to show the typical flora prevailing upon the various types of soil and under the various topographical conditions. The plants collected also allow one to judge of the influence of environment upon each species. Data were gathered regarding the forage and hay value of various species of grasses, and the proportions of the predominating grasses in the different areas were noted.

Area Covered by the Biological Survey.—The area over which it was possible to extend the biological survey included, in general, a short strip of the valley of the Missouri river on each side of the point where it is joined by Little Muddy creek near Williston, together with the Little Muddy valley and the greater portion of the upland drained by the Little Muddy and Sand creeks and their tributaries. This area comprises within it the land which is to be irrigated by the Williston Irrigation Project of the U. S. Reclamation Service. For a more detailed statement of the location of the area and a discussion of the kinds of land found here see the "Preliminary Report of the Soils of Williams County," by Rex E. Willard, page 122 of this issue.

Flora of the Area.—A rapid preliminary examination of the collection reveals the fact that at least fifty-five orders are represented by the number of genera shown in the following list:

Orders	Number of Genera
Alismaceæ	2
Amaryllidaceæ	1
Anacardiaceæ	2
Apocynaceæ	1
Asclepiadaceæ	1
Borraginaceæ	2
Cactaceæ	2
Campanulaceæ	1
Capparidaceæ	2
Caprifoliaceæ	1
Caryophyllaceæ	3

Chenopodiaceæ	2
Compositæ	25
Coniferæ	1
Convolvulaceæ	1
Cornaceæ	1
Cruciferæ	10
Cyperaceæ	2
Elæagnaceæ	2
Equisetaceæ	1
Ericaceæ	1
Gentianaceæ	1
Geraniaceæ	24
Gramineæ	24
Hydrophyllaceæ	1
Iridaceæ	1
Juncaceæ	1
Labiatæ	4
Leguminosæ	7
Lentibulariaceæ	1
Liliaceæ	4
Linaceæ	1
Malvaceæ	1
Nyctaginaceæ	1
Oleaceæ	1
Onagraceæ	3
Orobanchaceæ	1
Phytolaccaceæ	1
Plantaginaceæ	1
Polemoniaceæ	2
Polygalaceæ	1
Polygonaceæ	2
Primulaceæ	1
Ranunculaceæ	3
Rosaceæ	4
Rubiaceæ	2
Salicaceæ	2
Sapindaceæ	2
Saxifragaceæ	2
Scrophulariaceæ	2
Typhaceæ	1

(a) ALKALI LAKE, IN NORTHERN WILLIAMS COUNTY.

The white border is a thick crust of alkaline salts. The center of the lake is soft, muddy ooze. There is no water in the lake basin. Alkali loving plants grow in the salt covered mud along shore.

(b) THE ROLLING PRAIRIE OF NORTHERN WILLIAMS COUNTY.

Native prairie plants shown in foreground and left; flax in middle right; in center a white weed, which grows on neglected ploughed lands; young cottonwood trees in middle distance; unploughed prairie dotted with the claim shacks of homesteaders in distance. Ten miles south of Crosby.

Umbelliferæ	6
Urticaceæ	2
Violaceæ	1
Vitaceæ	1

Thus it is seen that at least 152 genera were represented in this area during the season from June 18th to August 18th. Doubtless the number of genera will be considerably increased after a careful study has made it possible to identify accurately all the forms in the collection. Beside these lichens and fungi were collected. The fungi represent several forms of plant disease. No attempt has been made to give the number of species, which will be somewhat greater than the number of genera. A complete classification will be left for a detailed report which will appear later.

Brief Economic Notes.—Among the grasses of the area the following are worthy of attention because of their hay and forage value:

Stipa viridula, Stipa coronata, Koeleria cristata, Agropyron caninum, Agropyron occidentale, Andropogon furcatus, Elymus Canadensis and Bouteloua oligostachya. One excellent field of timothy (Phleum pratense) was observed on section 22, township 156 north, range 102 west, showing that this cultivated grass is fairly hardy in this region when once started.

Comparatively few injurious weeds have been introduced and care should be taken to prevent its occurrence.

The following native or introduced weeds should be eradicated or kept carefully under control:

Camelina sativa (false flax), a bad weed in flax fields; Lichnis githago (corn cockle) and Brassica sinipistrum (mustard), troublesome in wheat fields; Taraxacum officinale (dandelion) a pest in lawns, not native in North Dakota, and just making a start in Williston; Hordeum jubatum (wild barley), an injurious grass growing in moist situations.

The poison oak or poison ivy (Rhus toxicodendron) is very abundant in the Missouri lowlands and occasional in coulees in uplands.

Water hemlock (Cicuta maculata), a plant which is very poisonous to stock, is quite abundant along Little Muddy creek and its branches where it has already been known to cause the death of cattle. The presence of wild flax (Linum perenne) is significant

as it grows native in the better flax producing districts of Europe, Asia and North America.

The wild hop (Humulus Canadensis) grows abundantly upon the low alluvial flats along the Missouri as in other similar situations throughout North Dakota. Owing to the dryness of the climate here, which would appear to be favorable for curing hops, the occurrence of the wild hop seems to indicate the possibility of developing a profitable hop raising industry by proper cultivation of suitable varieties.

The buffalo berry (Sheperdia argentea) produces a fruit which yields a good quality of jelly. Since it grows upon steep banks which are not suitable for cultivation it may be grown to advantage upon these otherwise practically worthless places.

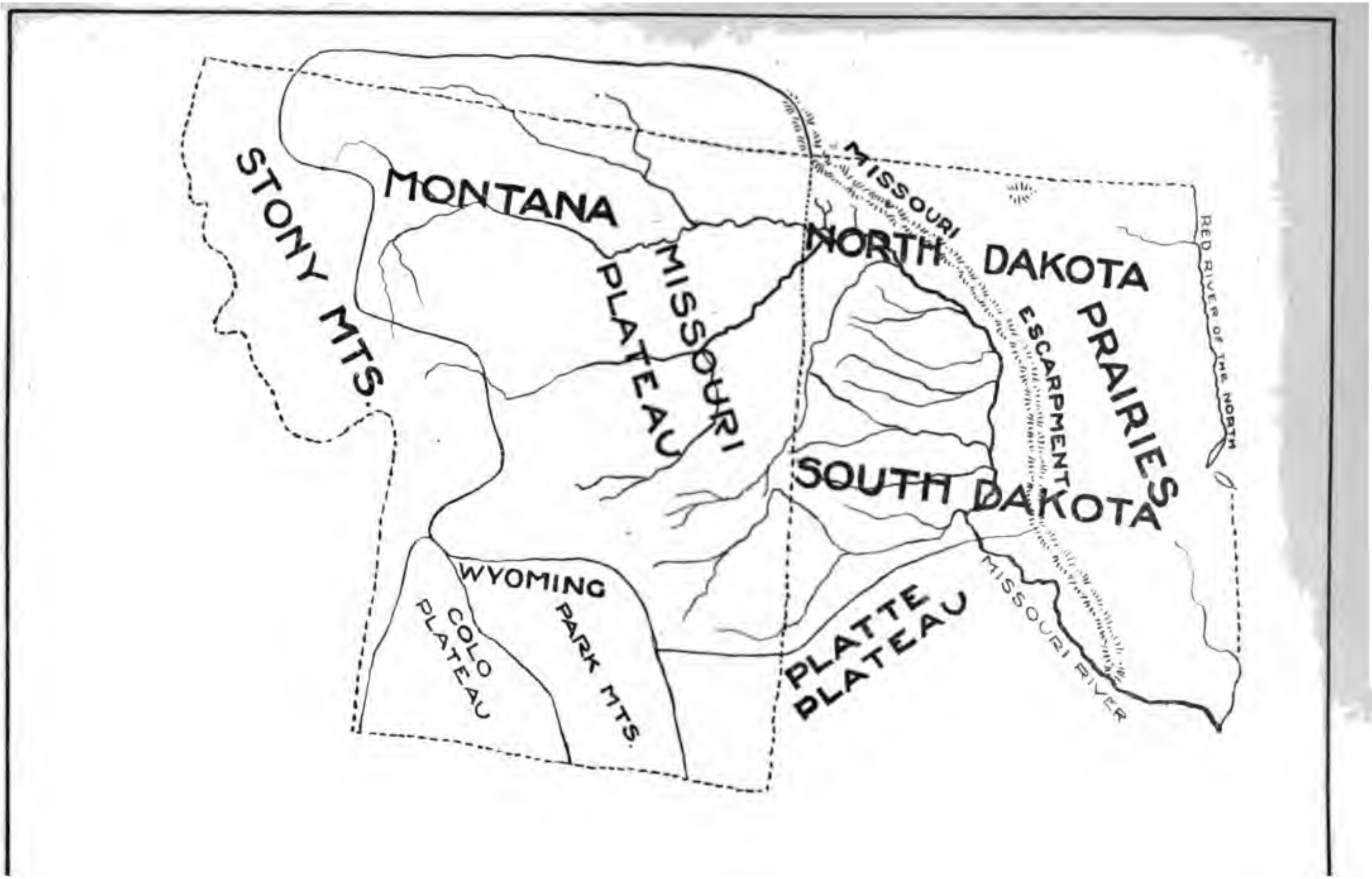
The wild gooseberry (Ribes grossularia) responds well to cultivation and yields a good quality of fruit. Some good thornless strains are to be found in this region.

The occurrence here of such large numbers of native leguminous plants indicates the suitableness of the soil for the production of legume crops such as peas, beans, etc. Their presence also gives assurance of a virgin soil rich in nitrogen because of the nitrogen producing tubercles situated upon their roots.

Two valuable drug plants should be mentioned: Polygala senega (Seneca snakeroot) is at present worth forty cents per pound and is steadily advancing in value. Brauneria augustifolia (purple coneflower) is rapidly increasing in importance and is much in demand in this country. There is also an increase in the foreign consumption of the drug. The people of this area are in a position to save these two valuable drug plants, which are abundant here, by proper cultivation.

Zoological Work.—Lists were prepared of the native mammals and birds observed in this region and some collections were made. Collections were also made of the insects, especially the butterflies, moths and beetles, noting especially those most common upon uncultivated areas.

Agricultural College, North Dakota, November 12, 1906.


STONY MTS.
MONTANA
MISSOURI PLATEAU
NORTH DAKOTA
MISSOURI
ESCARPMENT
PRAIRIES
RED RIVER OF THE NORTH
SOUTH DAKOTA
WYOMING
PARK MTS.
COLO PLATEAU
PLATTE PLATEAU
MISSOURI RIVER

DESCRIPTION OF THE PLATEAU REGION OF NORTH DAKOTA.

By H. V. Hibbard.

The state of North Dakota includes within the arbitrary boundary lines of its rectangular outline parts of two distinct geographic districts. The line separating these districts extends northwest-southeast approximately parallel with, and about sixty miles east of, the course of the Missouri river. More accurately described it crosses the state from the extreme northwest corner, southeastward through western Ward, eastern McLean and central Stutsman counties, to the southern boundary in the western part of Dickey county. This line marks very nearly the eastern-facing slope or escarpment of a great westward rising bench of upland, the Missouri Plateau. The escarpment rises abruptly to an altitude of 300 to 400 feet above the generally level plain on the east. (Plate XXIX.)

Escarpment.—The geographic significance of this natural boundary lies in the fact that here the Prairie Plains end and the Great Plateau begins. Extending north, perhaps, to the Arctic ocean, and south almost to the Gulf of Mexico, though less conspicuous as a feature of the landscape, this earth bench or escarpment is the continental threshold from the low central prairies to the Great plateaus which rise thence westward up the continental slope to the hills of the Rocky Mountains.

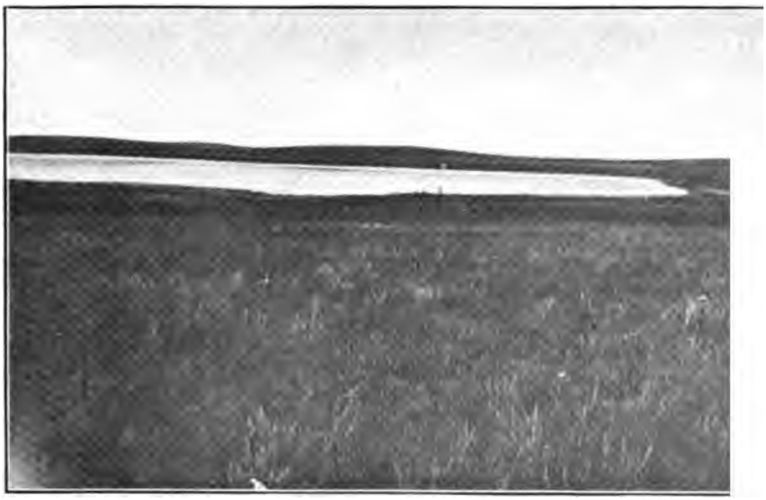
Boundary.—The southwestern part of North Dakota is thus included within the geographic district of the Missouri Plateaus. This plateau-province extends a short distance across the International Boundary line as far as the divide between the head waters of the Saskatchewan river and the southward-flowing tributaries of the upper Missouri river. Its southern boundary extends through central Wyoming as the divide between the Platte and Yellowstone rivers, and thence eastward, southward of the Black Hills, to the Missouri Escarpment in central South Dakota. A brief review of the principal features of this relatively large physiographic district

is here given in order to set forth more fully the geographic relations of that part within the state of North Dakota.

Great Plains.—The region known as the Great Plains extends from some distance beyond the Rio Grande river in Mexico through the United States and far into British America. This zone constitutes a geographic province, a fairly distinct natural division of the continental surface. A four-sided section from the northern end of the Great Plains belt is set apart from the surrounding country by natural boundaries and has been designated The Missouri Plateau District. An internal unity in the development and structure of its physical features also warrants this separation. The surface features of the region are simple but developed on a grand scale. The western border of the plateau, where it merges into the eastern flanks of the Stony Mountains, has an altitude ranging from 4,500 to 6,000 feet. Its eastern margin, the escarpment before mentioned, facing the glacial plains of eastern North Dakota, has an average altitude of about 2,000 feet. The bluffs of the Missouri in the western part of its course through North Dakota, toward which the principal rivers of the region flow, have an altitude of 2,000 feet. This gives a fall to the generally southeastward sloping plateau surface of about ten feet per mile. The rates of slope vary considerably in different districts but on the whole by far the greater part of the fall lies within the western half of the plateau. That is, the surface rises more rapidly as it nears the mountain region on the west. In the eastern part, considering a wide district, the country is almost level.

General Topography and Structure.—A conception of the general structure and topography of the district as a whole may be formed by considering the plateau a vast earth block, two miles in thickness and 500 miles square, built up of level-bedded rock layers. The western, somewhat ragged, edge is warped up against the mountain slope and beveled off by the corrosion of mountain streams; the eastern margin is worn down by erosion to a steep slope facing the prairies on the east; from above, the surface of the block has been deeply trenched by winding streams and sculptured by weathering; from beneath, under the western half of the block, the layers have been riven and thrust into by plugs and dikes of molten rock, and in many places pierced through and through by the forces from below, allowing the lava to flow out upon the surface. So forceful was the upthrust of the fiery columns

(a) ROLLING PRAIRIE, NEAR MANDAN.



(b) ALKALI LAKE, IN HILL COUNTRY NORTH OF WILLISTON.

Photograph taken August 19, 1906. The lake was entirely dry. White salt fc sheet bordering the lake. Mud or ooze occupies the interior part of the basin.

that the strata were lifted bodily, the bedded structure wedged and spread apart, and the upper layers completely overturned.

Laccolite Mountains.—These upwellings of molten rock in many cases assumed the form of vast reservoirs and lakes of lava; such fluid masses, since hardened into solid rock, were so enormous in dimensions that out of them the agencies of rain and rivers have carved whole mountain ranges. The mass of solidified magma out of which the sculpturing agencies formed a mountain is called a laccolite. An example of the upthrusted laccolite mountain is the Madison Range* northwest of Yellowstone Park. The peaks of this range now stand at an altitude of a mile above the general level of the plateau.

Lesser Plateaus.—The major streams and their great tributaries have deeply trenched the surface, forming wide valleys bordered by steep bluffs. Irregular masses capped by the horizontal layers of the great plateau have, in this manner, been blocked out by the tortuous streams thus forming lesser plateaus. Such tabular mountains are an especial feature of the western and central portions of the district. In the eastern part of the region and along the lower courses of the rivers erosion has been more effective in broadening the slopes and removing the original plateau surface.

The Missouri Plateau in North Dakota.—The foregoing general description applies to the plateau region as a whole; that part of North Dakota extending eastward to the Missouri escarpment differs widely in the minor details and in some of the larger features of its topography. Broad tabular uplands have disappeared and a wide undulating prairie-plain is the dominant feature of the landscape. (Plate XXX. A.)

Controlling Agencies.—Here, more especially than elsewhere throughout the plateau, the Missouri river and its tributaries are the controlling agencies of topographic development. The hills, ridges, valleys and plains constitute the topography. The work of excavation accomplished by the streams is represented by the amount of earth necessary to fill in their valleys up to a level with the highest hilltops. The hills down to the level of the lowest streams of the region represent the unfinished work of the rivers.

Divisions.—The Missouri river flowing diagonally across the state divides the North Dakota plateau region into two parts, viz: a wide plain sloping eastward to the river bluffs on the west, and

*Three Forks Folio, Montana, U. S. Geol. Atlas.

a narrow belt bordering the river and extending to the Missouri Escarpment on the east. (Plate XXIX.)

Slopes.—In the western portion the plain is characterized by slopes, wide and gentle for the most part, but steep and rugged in the vicinity of streams and their headwaters. Arranged apparently without order, yet every slope, gentle or steep, leads downward ultimately to the channel of a stream. The slopes form a system of drainage-planes merging into each other with decreasing steepness from the highest to the lowest. These slopes were formed by running water except in cases where gravity has directly caused the caving of banks and sides of lofty summits. Every hillside is also a part of the side of a valley. Hence, the surface of the country is said to be completely drained. Lakes and marshes do not exist. Streams have formed and are still controlling the features of the plain.

Comparison With Ice Plains.—To fully appreciate this type of topography it should be compared with that of the Prairies, the ice-made plains, extending eastward from the Missouri escarpment to the valley of the Red River of the North. Wide regions in this part of the state are wholly undrained. Since the retreat of the glaciers, beneath which all former drainage lines were effaced, the modern streams have not had sufficient time to extend their valleys and drain all depressions. Here hills exist without valleys. Marshes and lakes are obtrusive features of the landscape. (Plate XXX. B.)

Major Streams of the Plateau Region.—The Cannon Ball, the Knife, the Heart, the Little Missouri and the "Big" Missouri are the principal rivers of the plateau district of North Dakota. The Cannon Ball, Heart and Knife rivers rise in a narrow divide running north and south parallel with the Little Missouri river. The streams flow thence eastward in very tortuous channels to the Missouri river. Wide valleys bordered by steep bluffs have been eroded in the plateau surface. Extensive flood plains and terraces have been developed in the valleys. A remarkable feature of each of these rivers is its relatively long and narrow drainage basin. The tributaries are short; they join the main valleys at right angles, and in nearly every instance are intermittent streams. The streams flowing in the main channels during the summer season are diminutive when compared with the valleys which they occupy. These marked characteristics of the streams, viz: their parallel courses

(a) BUTTES NEAR DOGTOOTH, MORTON COUNTY.

Hard layers of rock protect the tops of the buttes. Grazing lands surround.

(b) SENTINEL BUTTE IN DISTANCE.

Sentinel Butte station on Northern Pacific railway, Billings county.

side by side, the long narrow region which each drains, their sinuous courses, wide valleys, extensive flats and terraces, find explanation in the climate of the region, the structure of the rocks and the slope of the plateau surface. The basins are narrow and parallel and approximately equal in extent because the long uniform slope and structure of the plateau gave to one stream no advantage over the other in the course of their development, but distributed the run-off meagrely and equally without showing favor to any one growing valley more than to another.

The disproportion between the valley and its stream during most of the year is due to the great variation in the volume of water carried at different seasons. Everywhere the major features of a stream valley are an expression of the vigorous activity of its flood waters. During the short period of high water the more swiftly flowing stream is armed with weapons of abrasion for battering away the high walls and bottom of its valley, and loaded with coarse material for building up flood plains and terraces. The small and gentle stream at low water does little except to modify the results of its more vigorous working days. This general law of streams is more especially applicable in the semi-arid plateau country where the precipitation in violent rainfalls and rapidly melting snows is carried by the rivers only during limited seasons of the year.

Another important factor in producing the relatively wide valleys with their attendent deposits is the long course of the streams with slight fall. The rivers, laden with debris from the easily eroded rocks of the region, do little downward cutting; dropping their loads at intervals only to take them up again. The streams swing heavily from side to side thus undercutting the bluffs and widening the valleys.

The low angle at which the tributaries enter the main valleys is also due to the slight decline of the slope of the main valleys.

The stage in the development of the river systems and their concomitant topography is to be considered in accounting for the mode of action of the streams at present. Rivers are said to pass through three stages in their growth and development: youth, maturity and old age. So, also, the topographic features, hills, etc., are at corresponding periods of the river, young, mature, and old. Young rivers have narrow valleys with broad-topped hills between their heads and branches; they are vigorous streams, cutting down-

ward for the most part but with large undrained territory surrounding; much of their work remains to be done. Such is the stage of the rivers in the western part of the Missouri Plateau.

A mature river has a wide valley; the vigor of down-cutting is diminished; all the region intervening is carved into valley slopes; none of the upland surfaces are flat; the river is working at its maximum rate of erosion and transportation. After this stage comes the course of decline in activity until old age—senility—is reached, when the river corrodes and transports no more; the steepness of its channel, which gave to it vigor in youth and maturity, is gone; hence, it flows slowly; all intervening hills are cut away to expressionless slopes on a featureless plain. The river's work is done.

The Heart and its two neighboring streams, the Cannon Ball and Knife rivers, have passed the stage of maturity and are on the decline. Only in isolated places does any of the old plateau surface remain; these are the hills with flat summits, the true "buttes" of the region. (Plates XXXI. A and B; XXXVIII. B.) They are few and represent the fragments of the unfinished task of maturity. For the most part the plateau surface has been cut away and the hills lowered.

The Little Missouri River.—The Little Missouri river rises near the junction of the Missouri Plateau with the mountains, in northeastern Wyoming, and between the head waters of the Belle Fourche and Powder rivers. It flows thence north by east to central McKenzie county, North Dakota, where it swings broadly to the east and flows to the Missouri river.

Basin.—The Little Missouri resembles the other rivers above described in this part of the state in having a long and narrow drainage basin. Its length is about 320 miles; in width it varies from a maximum of fifty miles to a minimum of twenty-five miles. Throughout by far the greater part of its course the mean width is nearer the latter figure.

Relation to Other Streams.—By reference to the map it will be noted that the Little Missouri stands in a peculiar relation to its neighboring streams. It flows obedient to the long northward slope of the plateau but dangerously near the hip, or edge, where that breaks down to the short, east-facing slope. It thus crosses close against the head waters of the Moreau, Grand, Cannon Ball, Heart and Knife rivers, separated from their head valleys only by

(a) BURNING COAL MINE, NEAR SULLY SPRINGS, BILLINGS COUNTY.

The walls of the crevices were red hot at time photograph was taken. This mine is said to have been burning for 25 years.

(b) "THE SENTINEL." SUMMIT OF SENTINEL BUTTE.

In the holes underneath the rocks wolves make their den. Sandstone rock.

very low and narrow divide. The rivers above mentioned have pushed their heading valleys westward up the slope, encroaching upon the territory of the Little Missouri until at several points the ridge parting their waters is less than six miles from the banks of the latter stream. (Plate XXIX.)

Piracy.—The Little Missouri is in imminent danger of having its basin invaded and upper waters "pirated" away by any one of its unfriendly neighbors on the east. This process of "beheading" a river, or of diverting the waters of one stream into the valley of another is called "piracy." The invading river is, of course, the "pirate." The Little Missouri is most unfortunately located in this respect, having such a threatening number of would-be pirates on its eastern flank. This process of robbing the Little Missouri of its waters has already been initiated by the Belle Fourche river, a tributary of the Cheyenne.*

The upper 150 miles of the Belle Fourche, that portion extending from the sharp bend northwest of the Black Hills, originally belonged to the Little Missouri. The place where the latter stream was beheaded, the channel of the Little Missouri, is the "Stoneville Flats" (see 10, Plate XXIX.) shown on the topographic map of the Alladin Quadrangle. This cutting up of the Little Missouri's valley piecemeal and diverting the sections, once begun at its head waters, is more likely to be continued by the streams successively heading against its course lower down; each removal weakens the power to intrench its channel deep enough to be beyond the reach of its foe.

Bad Lands.—The basin drained by the Little Missouri is, throughout its larger part, the region of the Bad Lands. The river flows through the center of the Bad Land belt. The tributaries descend to the deeply intrenched main streams by steep gradients; these short branches fed by storm waters have cut deep into the soft clay beds. The heading coulees extend out most intricately in all directions. There is little weathering, no soil except in the valley bottoms, and erosion in its most vigorous phase is the controlling factor. The result is a jumble of topographic forms that beggar description. There is no beauty here. Steep hills with ugly bulging flanks stand foot to foot, corrugated up and down their naked sides with rain gutters. In places, hills like monstrous earth-warts are scattered over the surface of a level plain. Sharp-crested ridges

*Aladdin Folio, U. S. Geol. Atlas.

wind in and out forming cirques and amphitheatres at the heads of streamless valleys below. Vertical pillars (Plate XXXII B.) and walls of clay, the veritable mud fences of proverbial fame, stand along the sides of deeply worn channels. From within the valleys no extended view can be obtained; the observer is surrounded by vertical or steep-rising slopes on all sides. (Plate XXXIII A.) From the top of a lofty butte the landscape appears a myriad of hilltops closely set together and massed back of each other until they blend far away in a level sky line. (Plate XLV B.)

Structure.—In this region, where the streams have deeply dissected the plateau the structure and composition of the rock are readily seen. They are built up of horizontal strata, "one layer above another like boards in a lumber pile." The composition is fine sediment, beds of clay and sand for the greater part alternating with each other.

Name.—The Bad Lands were so named by the early French explorers because they found them lands difficult to travel through. The country seems to have sustained that reputation ever since. There is practically no direction of traversing the region except by way of the waters. All roads follow the courses of winding streams.

Utility of the Bad Lands.—The Bad Lands constitute an excellent grazing country. Extensive fields of alfalfa are grown on the flats and bottom lands along the Little Missouri and its tributaries for winter forage. Two crops of alfalfa may be matured in one season on the same land. Excellent water from wells is obtained at depths of twenty to sixty feet.

Coal.—Beds of lignite coal, varying in thickness from a few inches to upwards of eight feet, are found interstratified with the soft rock layers. Throughout the plateau district of North Dakota as well as in the Bad Lands this lignite outcrops from the hillsides or lies in extensive seams as the foundation layers of the buttes. (Plates XXXI B and XXXIII B.)

A Burning Mine.—In a few places in the Bad Lands country the outcropping beds of coal have become ignited and are now burning back under the hills. As the fire advances beneath the surface the baked earth above opens in great crevices, admitting a down draft of air and maintaining further combustion. Such a "burning mine" is at present located close to the tracks of the Northern Pacific Railway near Sully Springs. (Plate XXXII A.) Here a crater-like

(a) "THE PALISADES," MEDORA, BILLINGS COUNTY.

The side of the large butte appears vertical as viewed from the depot. On the top is a broad, flat, grass covered plain. A coal seam underlies the hill.

(b) COAL MINE AT CARSON, MORTON COUNTY.

Section 24, township 134, range 87. Workable vein about six feet thick.

depression about 500 feet in diameter has been formed above the burning coal. The sides of wide fissures opening deep into the earth glow white hot and red from the fires of the subterranean furnace. Great volumes of gases, with stifling and sulphurous odors, arise from the crater, but no smoke or flame; the combustion is complete. The fires advance slowly but with great persistence against the bed of coal. The vein at Sully Springs is known to have been burning during the past twenty-five years. In that time the crater has moved perhaps 100 feet northward. The advancing fire leaves behind it a trail of red-baked clay and earth fused into scoriaceous masses. This process if extensive enough in the past ages would account for the red strata so widely shown outcropping on the hillsides of the Bad Lands.

Sentinel Butte.—(Plates XXXI B and XXXII B.) Throughout the southern part of the plateau, standing back from the streams, usually on or near their divides, are sharp hills, serrated ridges and flat-topped buttes. Their summits, capped with resistant sandstone, mark the level of the old plateau surface upon which the streams began their work of valley development. They are remnants of the unfinished work of the streams at the stage of maturity, and are termed by geographers Monadnocks. Such a Monadnock is Sentinel Butte, located three miles south of a village of the same name on the Northern Pacific Railway. From its flat top, 600 feet above the surrounding plain, undulating and hilly, the landscape spreads out to view in all directions. The country beneath appears as a great map in midsummer, hills showing the gray of range lands, and valley the green and yellow of wheat and forage crops. The hill was used in the early Indian fighting days of the northwest by the United States troops as a vantage point of observation; hence the name Sentinel Butte. Two of Custer's scouts, killed by the Indians, are buried near the top of the hill. Their grave is marked by a little cairn and a rough slab of sandstone.

A vein of lignite coal ten feet in thickness underlies apparently the entire base of the butte. From an outcrop of the vein on the north side of the hill a coal mine has been developed and furnishes a good grade of fuel at the cost of mining only.

The Plateau East of the Missouri River.—That part of the Missouri Plateau extending east from the Missouri river to the escarpment joining the prairies, differs in its topographic features and

drainage from the section to the west of the river. During that time in the earth's history known as the glacial period the front of a great continental glacier lay along the crest of the Missouri escarpment. The southwestward advance of the ice over the prairie region from the enormous snow fields of Labrador was doubtless stopped by the rising margin of the plateau. The debris carried by the glacier, as fragments of rock, clay and boulders, was lodged in the form of a broad hilly belt at the edge of the melting ice. This belt of hilly topography, with its accompanying marshes, lakes and undrained depressions, constitutes the first and outermost moraine of the continental glacier. The region is known as "The Hill Country of the Missouri Plateau." From the melting ice front there flowed to the Missouri river glacial streams carrying great quantities of sand and gravel. The valleys of these short rivers, built up with extensive terraces, are prominent features of the topography between the Hill country and the Missouri river. Both the hill country and the valley region are excellent grazing lands, and large tracts are being rapidly brought under cultivation. Wells from twenty to seventy feet in depth yield abundant water.

Industries.—All the plateau country of North Daokta is comparatively new, but settlers are moving in and land values are rapidly rising. (Plates XXXIV A and B, and XXXV A.) Stock raising is at present and will probably continue to be the leading industry. Fine herds of cattle, horses and sheep feed on the nutritious grasses of the plains. (Plate XXXV B.) Ranchmen have introduced the better breeds of stock and realize large profits on this branch of industry. When crops adapted to the soil and climate are introduced farming will become a larger element of industry than at present.

(a) FOUR SISTERS "HOLDING DOWN CLAIMS."

Vandalia, Williams county.

THE HOMES OF THE FOUR SISTERS SHOWN IN (a).

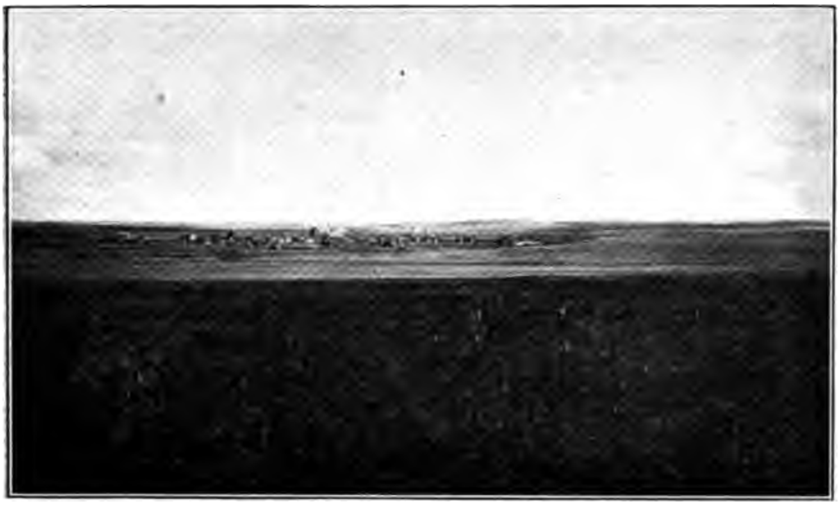
Houses made of sod.

(a) RUSSIAN HOUSE AND STABLE.

In the hill country of Williams county.

(b) ONE OF THE SOURCES OF NORTH DAKOTA'S WEALTH.

Herd near Mandan, Morton county.



(a) HEBRON, MORTON COUNTY.

The soils of the rolling prairies have been derived from the country rock almost entirely. Located near the extreme edge of the glaciated territory. Granite boulders occur.

(b) DICKINSON, STARK COUNTY.

No granite boulders (drift) occur. The soils are those that have come from the native rocks.

A PRELIMINARY STUDY OF THE SOILS WEST OF THE MISSOURI RIVER.

By Daniel E. Willard.

West of the Missouri river in North Dakota is a vast region about which many erroneous opinions have been held by people living in other states and in the eastern portion of our own state. North Dakota is so large in extent that it is not surprising that there should be many people who have lived two decades in the state and yet have no definite knowledge of the character of many parts of the state. Many persons who have lived and prospered during a goodly period of their lives in the Red River Valley, or other eastern portion of the state, have never been west of the Missouri river. It is not strange, therefore, that the idea has gained wide acceptance that the country west of the Missouri river is "Bad Lands."

This vast domain has but recently come in for recognition as an agricultural region. So much success has been attained in this region in the grazing of cattle, horses and sheep, and so little attention has been given to general agricultural pursuits that, until recently the whole country west of the Missouri has been generally thought to be adapted to nothing except grazing.

Within the past three years a great influx of settlers whose purpose has been general farming rather than exclusive grazing, has largely changed the sentiment regarding this country, as it has also changed the character of the pursuits of the residents in this part of the state. "Ranching," a provincial term for the grazing of stock in large herds on the broad ranges of government or other unoccupied land, has largely given place to the more intensified methods of diversified farming, except in those localities where, due to the natural roughness of the land and its consequent ill-adaptability to diversified farming, and its more profitable use for grazing, stock raising is still the dominant industry. The quest of homeseekers, both from older and more thickly settled states and from foreign lands, for free government lands, has made the

region a mecca for immigration. Farmers now live where but one, two or three years ago was the open range and the unbroken sod.

Because of these conditions little investigation of the character of the soil or of the general conditions which enter into the problems of diversified farming has been made in this region. Now that the land is being so rapidly settled by farmers, and homeseekers are looking to the newer sections of the west for low priced lands, many inquiries are being received for information relative to the soils and the agricultural conditions and possibilities of this portion of the state.

No detailed investigation of limited areas, such as have been in progress during the six years since the inauguration of the agricultural survey of the state, have as yet been completed, but reconnaisances looking toward future more detailed surveys have been made, and from these preliminary investigations it is possible to make some statements and give some information regarding the western portion of the state such as will, it is hoped, assist those who are unfamiliar with the conditions and who are seeking for information regarding the natural resources, advantages and disadvantages of this region in some measure.

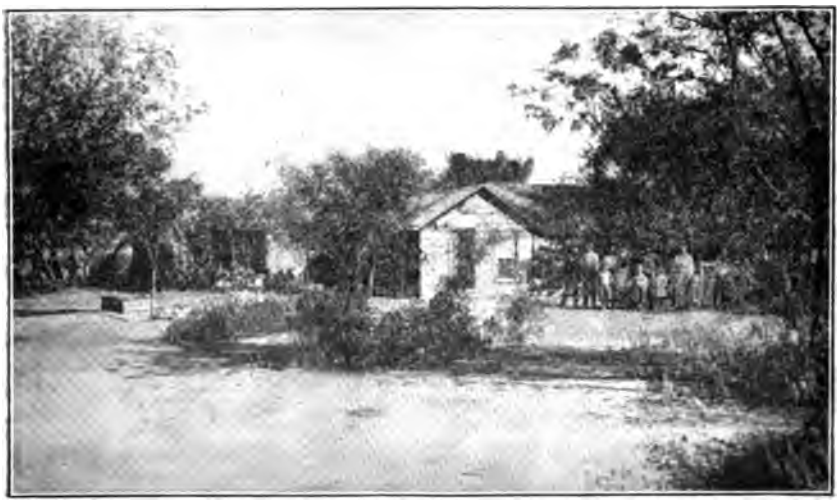
Questions of climate, rainfall, soils, water supply, available fuel, means of transportation, and the like, are those upon which the prospective homeseekers or recently settled homemaker desires information, and about which the department of the Agricultural College having in charge this survey, is most frequently receiving inquiries.

A brief and necessarily somewhat general *resume* of what has been learned about the great trans-Missouri domain of North Dakota will be attempted in this paper, the subjects suggested above being each considered, and in the order in which they have been mentioned.

Climate.—The climate of the western part of North Dakota is of the healthful and invigorating kind that characterizes the whole state, though there may be said to be a little odds in favor of the western portion as compared with the eastern. Warmer currents of air from the Pacific ocean flow southeastward after crossing the great mountain axis in the Canadian northwest, and these warmer winds influence the climate. On the whole the climate is wholesome and satisfactory, and few states afford more healthful and invigorating conditions. The winters are cold, that is there are times of extreme

(a) JACK WILLIAMS' RANCH.

Located in south part of township 149, range 96, just outside the Bad Lands of the Little Missouri. Rough, rolling prairie.

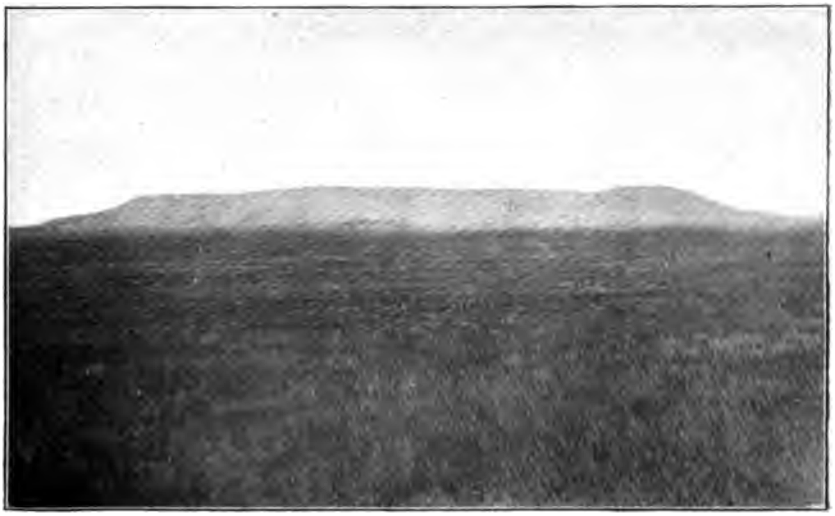


(b) HOME OF E. PAULSON, ON KNIFE RIVER.

Native trees. A good North Dakota family.

(a) SCHOOL HOUSE, NEW ENGLAND, HETTINGER COUNTY.

A stone building made of wood. The walls are constructed of broken blocks of petrified wood, gathered from the vicinity. Fragments of same at right.



(b) WEST RAINY BUTTE, EASTERN BILLINGS COUNTY.

Gently rolling, grassy prairie surrounds the butte. Cattle grazing in the distance. Taken in August. The white patches show outcropping ledges of rock.

severity, as indeed there are in any of the northern states. The weather is not more trying, however, than that of northern Illinois, Iowa, southern Minnesota, or western New York. Extravagant reports of temperatures are given wide circulation and are often accepted as true without verification. If any one will take the trouble to consult the government records no justification will be found for such statements as 47 degrees, 50 degrees, or even 55 degrees, below zero, although such reports go abroad. In very rare instances 39 degrees or even 40 degrees have been known, but these temperatures are not common.

The error, it may be explained, grows out of the common use of cheap and unreliable thermometers. These thermometers have not been tested and vary from one or two degrees to as much as ten or twelve degrees. Thus a thermometer that hangs at the drug store corner may register 46 degrees, 48 degrees, or even 50 degrees, or more, while in reality the registered thermometer at the same moment and in the same locality registers 34 degrees, or 36 degrees, or even 39 degrees, though the last named is very rare for North Dakota.

A feature of the climate in this region is its uniformity. It is not the extreme cold of winter or the high heat of summer that causes the greatest detriment to health, but rather the sudden changes through wide ranges of temperature. The greater evenness and continuity of the conditions in North Dakota saves much of the trying character of winter, and the strain upon the health which is experienced in the more easterly northern states generally.

Rainfall.—The question of the annual rainfall of this region is one about which there is no little misconception. It has long been currently accepted that the rainfall west of the Missouri river is not sufficient to make general farming safe and successful, and therefore profitable. This generally accepted opinion, though requiring evidence to remove, is not, in the opinion of the writer, a true verdict. The fact of the amount of the annual rainfall is one that cannot be readily determined by the average person from general observation, nor yet by the closer observation of the frequency and severity of storms. Even if one were to keep a written record of the days when rain fell, a thing that is very rarely done, still he would not have a reliable record of the rainfall. It is only by the daily reading of a scientifically constructed gauge that a correct record can be obtained. Within recent years a considerable num-

ber of gauge stations have been established, and these give a reliable basis for estimating the rainfall for any particular locality.

Probably one reason for the unfavorable impression regarding the sufficiency of the rainfall in this region has been that during the time since this part of the state has been occupied by white settlers almost no attempt at cultivation of the soil has been made, and when such attempts were made no particular attention was paid to the matter of cultivation or the adaptation of seed to the conditions of this region. Stock-raising was the principal industry, and general agriculture was not considered at all. When, therefore, an occasional small area was ploughed, seeded, and neglected, and no satisfactory crop harvested it was assumed that the trouble was due to lack of moisture. It might be said in this connection that if similar methods of farming were used in Illinois or Iowa loss in quality and quantity of crops and financial failure would most certainly follow.

Systematic records of rainfall covering any considerable number of years have been kept at only a few stations in this newer part of North Dakota. Comparison of the average rainfall, as recorded at these stations, with the records of stations in other parts of the state where no question has ever been raised as to the sufficiency of the rainfall to produce profitable crops, furnishes a basis for an opinion which at least would seem to contain the elements of fairness.

The annual precipitation* for four stations located at points either on the Missouri river or west of it are given below, these records being for the period of fourteen years, from 1892 to 1905, inclusive. These are the only stations in this portion of the state for which complete records are available for this period.**

	1892	1893	1894	1895	1896	1897	1898
Bismarck	18.17	13.74	14.32	16.92	16.63	14.33	13.67
Dickinson	***	11.64	***	***	18.48	***	11.92
Fort Yates	21.23	16.30	12.20	12.96	20.08	18.32	19.55
Williston	14.26	15.45	17.76	17.07	22.04	12.19	14.44

*By precipitation is meant rain, snow, hail, sleet, or any form or moisture that is "precipitated" or falls from the clouds. All frozen forms of water are reduced to equivalent amounts in the liquid form.

**Compiled from the records of the United States Weather Bureau, Bismarck, N. D.

***Records wanting for certain months, so that the correct amount for the year could not be given.

(a) BUTTES, NEAR CHERRY CREEK.

Township 149, range 96. Showing how stony areas are developed from hard layers of rock. The butte in foreground is capped with hard sandstone. A hard shelf also projects at the right.

(b) BUTTE, NEAR LITTLE MISSOURI RIVER.

Township 149, range 96. In edge of Bad Lands. Butte surrounded by rough prairie half covered with grass.

(a) VIEW LOOKING EAST, SOUTHWESTERN STARK COUNTY.

Gently rolling prairie, slightly broken by streams.

(b) VIEW LOOKING WEST.

Camera stood in road shown in foreground of (a) for both views. Illustrates the abruptness of the change in topography from prairie to bad lands.

(a) SCHAFER P. O., M'KENZIE COUNTY.

The new town of Schafer is half a mile to the right. Broad, flat meadows on Cherry Creek 'bottoms.' One of the finest springs in the state (or world) burst out of hillside in the foreground. (See Plate L A.)

(b) CORRAL AT SHAFER, SHOWN IN (a) ABOVE.

	1899	1900	1901	1902	1903	1904	1905
Bismarck	15.47	17.88	15.59	15.95	17.96	14.17	17.19
Dickinson	17.27	11.78	12.92	*	*	15.19	16.55
Fort Yates	17.71	16.80	13.42	16.49	15.00	17.30	*
Williston	12.61	15.81	18.36	16.85	17.69	9.44	10.66

*Records wanting for certain months, so that the correct amount for the year could not be given.

Soils.—The soils of a great part of the region lying west of the Missouri river are different in origin from the soils of most of the state, and therefore differ very considerably in character from those of other parts of the state.

The soils of any region are determined by the geological conditions that have prevailed in the region. The soils of this region therefore differ from those of other portions of the state because of a different set of geological conditions through which the region has passed.

Most of the state of North Dakota falls within that great portion of North America which was covered by the ice of the Great Ice Sheet during what is known as the Glacial period. (See Plate III.) The surface formation in the region over which this great sheet of ice passed is often spoken of as "drift." This drift formation is made up of the broken and pulverized fragments of the rocks of the land surfaces over which the ice passed together with the original soil that covered the face of the landscape before the invasion of the ice. In those regions, on the other hand, where the ice sheet did not extend (See Plate III) the soils have not been modified by this agency, and consist of the residual material arising from the disintegrating or weathering of the rocks which form the foundation of the landscape. The soils in such a region are spoken of as residual soils, as distinguished from the drift soils just referred to.

The soils of any particular locality in a region where the great ice sheet has never been will therefore be made up of the same materials that composed the rocks in that locality, minus whatever has been removed by the process of erosion.

The rocks of the great Missouri plateau, of which the region west of the Missouri river is a part, are mostly shales, sandstones, and clays. The soils are residual formations derived directly from the

decomposition of vegetable matter such as has grown upon the landscape during long ages.

Among the most common types of soil in the northern states are sands, sandy loams, loams, clay loams, and clays. These terms have to do with the character of the soil as to its texture and composition. Sandy soils are derived, directly or indirectly, from sandstone rocks or from rocks which when broken up by weathering yield sand fragments.

Clay soils are derived from rocks that contain argillaceous or clayey materials, such as shales, slates, and clay-rock. Loams are soils that contain some clay and some sand, and these are further described as sandy loams or clay loams according to the relative amounts of clay and sand. Sandy soils are often spoken of as "light," and clay soils as "heavy." Not that one is lighter or heavier in weight, or lighter or darker in color, but looser or more compact in texture. "Light" soils may be dark in color and "heavy" soils may be light in color.

Subsoil is that portion of the surface formation which lies below the superficial few inches, and differs from the soil proper in color, texture, and amount of organic matter contained.

In the classification of soils the subsoil as well as the surface portion is considered, inasmuch as the character of the soil, so far as agricultural conditions are concerned, is determined by the subsoil as well as by the character of the soil proper.

The soils of Oliver, Mercer, McKenzie, northern Dunn, and eastern Morton counties are in part glacial soils, that is, the soils are not entirely residual (derived from the rocks in the localities where they occur), but have been in part transported from some distance by the great moving ice sheet. A belt having an indefinite edge to the westward lies along the west side of the Missouri river, which belt represents the western limits of the glaciated area of North Dakota, and of the continent of North America. (See Plate III.) This "belt" of land along the west side of the river shows by the character of the soils and rocks that the great continental glacier was once here. The western portion of the belt fades out and becomes undistinguishable from the land farther west over which the ice did not pass, but the eastern part of the belt is sufficiently modified as to the soils and the landscape features to be readily recognized.

(a) BAKER'S RANCH, CENTRAL BOWMAN COUNTY.

Roughly rolling prairie, mostly grass covered, east of the Short Medicine Pole hills. The walls of the house are of sod. The walls of the barns and the high barnyard fence are built of a very hard quartzitic rock quarried from a hillside nearby.

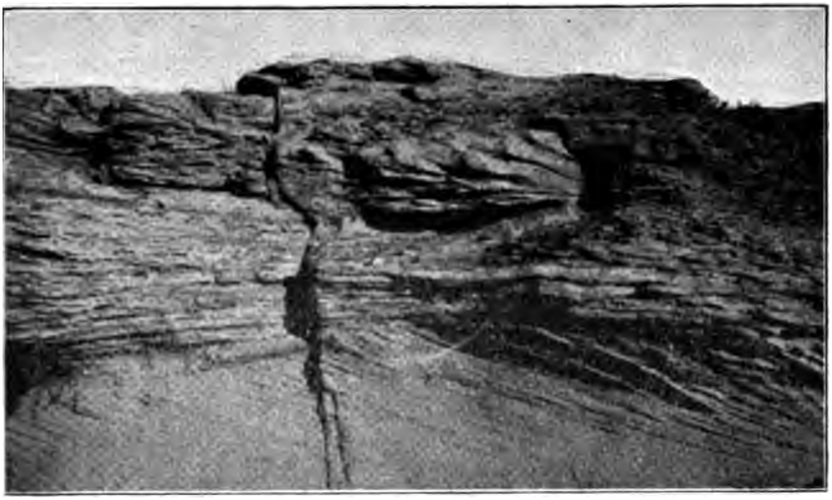
(b) SANDSTONE CONCRETIONS, NEAR SCHAFER, M'KENZIE COUNTY.

(a) VIEW IN BAD LANDS SOUTH OF WILLISTON.

This panoramic view was taken from a high butte immediately south of the Missouri river, from Bell's ferry. At about the horizon line of the picture the grassy prairie **is** reached.

(b) NAKED CLAY BUTTE WITH FLUTED SIDE.

Cherry Creek, south of Schafer.



(a) CREST OF HILL IN RAGGED BUTTES, M'KENZIE COUNTY.

Showing cross-bedded strata of sandstone.

(b) BROW OF EAST RAINY BUTTE, BILLINGS COUNTY.

The top of the butte is nearly level and thinly covered with grass. The top strata of the butte is hard sandstone. The almost inaccessible sides are strewn with large and small fragments of sandstone rock. The prairie surrounding is 500 to 600 feet below the top of the butte.

For a distance of 15 to 30 miles west of the river the soils are considerably modified by the presence of drift. Farther from the river the presence of drift, and therefore the presence of the one-time ice sheet, is shown by the occurrence of scattering boulders of granite. Where only a few boulders occur, and these scattered widely so that the traveler sees a single one or a cluster of them only at intervals of many rods or even miles, the soil is not thought to have been greatly modified by the presence of drift, but is largely residual in its origin. In the region nearer the river the occurrence of boulders is common, and the soils show evidence of the influence of drift sands and gravels, silts and clays.

The soils nearer the river resemble the soils on the east side of the river and the interior portion of the state. The soils in the region farther west than any boulders of granite occur constitute a different class of soils. These last, as indicated before, are residual soils formed from the rocks of the region. Along the western portion of the indefinite belt referred to the soils are influenced less and less by the drift the farther west, and more and more by the drift farther east.

The soils, therefore, in the belt bordering the Missouri river on the west constitute a transition type from the glacial soils of the eastern portion of the state to the non-glaciated or residual soils of the southwestern portion.

The soils in any region are an expression of the geological processes that have occurred there. The soils in the regions beyond the limits reached by the great continental glacier will have a different geological history from the soils where the action of the great ice sheet affected the whole land surface.

In western Morton, southern Dunn, Hettinger, Stark, Billings and Bowman counties the soils are residual in character, that is, have been derived from the layers of rock which underlie the landscape. These rocks were originally deposited on the bottom of a shallow sea, and when first thrown down as sediments were in the form of mud and sand. During the lapse of time they became solidified into stone or rock. The layers or shelves of rock that jut from the sides of buttes, and the crags and pinnacles that project from the crests, are eroded edges or parts of the rock layers that were once the muddy or sandy bottoms of the sea. (Plate XLIV A, B.) All the rock that used to be between the hills, that is, the material that once filled the present valleys, has been removed by erosion and

"carried down stream" by the creeks and rivulets, and the waters of melting snows and spring rains that flow off from the land. (Plates XXXIX A, B; XL B; XLI A; XLIII A, B; XLV B; XLVI A.)

It is as a result of these erosion processes acting upon the rocks of the region, together with the effects of weathering, that the present soils have come. Where the rocks are sandstone the soils are pretty apt to be sandy, because the sandstone is merely sea sand compacted into stone. When the stone breaks up by the action of frost and sunshine the rock becomes sand again. If a good deal of running water goes off from any particular region where it is sandy the more clayey parts are carried away by the water, and the heavier sand is left behind. It is this process of disintegrating and carrying away the finer parts of the soil that makes the flood waters of the streams roilly or muddy.

The soils in the region west of the drift covered belt referred to are determined in character by the kind of rock in the particular region and the character of the erosion or washing that have taken place. Apart from the bottoms and benches along the streams the soils are of about four general types: (1) the heavy lands in the lower places (often locally called "gumbo"); (2) the sandy-loam soil of the rolling prairies, which is also underlaid with a clay subsoil; (3) the soil of the higher hills and ridges (Plates XLII A, B; XLVII B), which is often sandy or stony in character; and (4) the eroded and dissected or broken portions, called "bad lands." (Plates XXXIX A, B; XL B; XLIII A, B; XLV B.)

The "gumbo" soils in the valleys are often in nearly level tracts. (Plates XL A; XLIX A.) In fact it is not infrequently the case that the land is so nearly level that drainage is difficult. The texture and character of the soil in these places is that of a fine grained and compact clay, and is not infrequently somewhat alkaline. The clay appears to have been derived from a shale-clay formation which is one of the rock formations of this region. In this shale-clay are some alkaline mineral substances which were deposited with the muds upon the ancient sea bottom. These mineral substances accumulate in the low places where there is not drainage sufficient to carry them away.

(a) W. W. PHELPS' RANCH, GREEN RIVER, NORTH OF DICKINSON.
Showing the broad floodplain, with slow meandering stream.

b) VIEW IN THE BAD LANDS OF THE UPPER LITTLE MISSOURI RIVER.
The Little Missouri flows from left to right near center of picture. Tributary stream crosses foreground.

(a) IN VALLEY OF CHERRY CREEK, BELOW SCHAFER.

Clay buttes with naked sides bordering the flat-bottomed valley, through which meanders the sluggish stream.

(b) RUSSELL'S RANCH, SOUTHERN BILLINGS COUNTY.

Cut bank of Sand creek at right. Characteristic ranch buildings. A home for a quarter of a century.

(a) IN THE EDGE OF THE BAD LANDS.

East of Cherry creek. Shows the hillsides half grass covered.

(b) VIEW IN VALLEY OF CHERRY CREEK, BELOW SCHAFER.

Shows the naked hillsides on either side of valley and the flat bottom of the valley. The meandering course of the stream is shown by the line of trees.

(a) CUSKELLY RANCH, KILLDEER MOUNTAINS, NORTHERN DUNN COUNTY.

The top of the "mountains" is a nearly level plain. Hard strata of sandstone project from the sides. The top of the plateau is about 700 feet above the surrounding prairie. A fine spring gushes from the hillside back of the house.

(b) "HOME MADE" IRRIGATION PLANT OF E. PAULSON, ON KNIFE RIVER.

The water is hoisted from the river by means of the water-wheel upon the "bench land." along the valley.

The sandy-loam soils, when underlaid with a clay subsoil, are the best soils of this region for general agricultural purposes. And this type of soil embraces by far the greater part of the agricultural lands* throughout this region.

The soil is described as a sandy loam. This means that in texture the soil is more light and porous than the heavier clay soils of the low places described above, and yet contains enough clay to give body and firmness to the soil. It is usually dark in color due to the presence of organic matter. When underlaid with a clay subsoil this gives support to the soil by holding the soil moisture from draining away too rapidly and furnishes a supply of moisture from below to the soil above during the warm summer months when crops are growing.

In the third type of soil referred to, if indeed it may be called a soil type, the surface formation of the hills and ridges, is included the high or stony parts of the hills or buttes, and the higher ridges which are capped with sand derived from a sandstone rock layer, but still covered with grass or other vegetation. (Plates XLII A, B; XLVII A; XLVIII A.) This type is such as will furnish pasturage, but will not generally be of much value for other farming purposes.

The fourth or "bad lands" type is that characteristic kind of landscape which is widely known as "bad lands," but which in reality should be called, as first named by the early French explorers "bad lands to travel through." These lands are not adapted to general farming, and are not included in the general classification of agricultural lands. They are lands well adapted to grazing, but are inaccessible to general farming. The hillsides are often naked of any vegetation, the layers of shale, shale-clay, and sandstone extending to the surface without covering of any trace of soil. (Plates XXXIX A, B; XL B; XLIII, A, B; XLV, B; XLVII B.) Soils derived directly from the eroism or washing and disintegration of these naked rocks accumulate in the valley bottoms, (Plate XVII A, B.) and these soils support nutritious and valuable varieties of grasses, and produce large crops of alfalfa, timothy, oats, barley, and garden crops when cultivated. The areas that are available for cultivation are however usually limited, so that the

*By agricultural lands is meant all those lands that are in any reasonable sense fit for general farming, and the term includes all the land that might reasonably be ploughed, but does not include rocky hill crests or "bad lands."

general fact remains as stated, that these lands are best adapted to grazing and not to general farming.

The soils of the stream bottoms and benches comprise a group of soil types falling in a class by themselves, and differing from those above described. The flats and benches along the stream courses represent deposits made during the flood stages of these streams. (Plates XLI A; XLVI B; XLIX, B.) By flood stages is here meant those times in the past when vastly larger streams flowed down these water courses than any that ever flow in them now even during the highest freshets.

It is not necessary to give here any geological history of these streams, but merely to refer to the facts that have a bearing on the present character of the soils.

The soils of the broad level benches that border most of the larger streams frequently have a gravelly subsoil. This renders the problem of their successful use for farming lands a somewhat critical one, since the gravel subsoil permits of ready underdrainage, and does not afford a sufficient conservation of the soil moisture for cereal crops during many seasons.

No general rule can be laid down however for all these lands. The soils and subsoils represent floodplain deposits of streams heavily laden with sediment. Such streams deposit their burden of earth materials whenever the current is slackened. The soils will differ therefore in different places, and often within short distances, according to the conditions which effected the rate or flow of the waters of the stream.

The particular consideration of these stream deposited soils must await the more detailed investigation of a systematic soil survey before they can be correctly mapped and the types defined.

In many instances the flats or bottom lands constituting the lowest extensive floodplain are sufficiently heavy to make valuable farming land, and some fine hay-meadows may be developed on these lands. (Plate XLVI A.) On the other hand some of the bench lands, while level and beautiful to look upon, are too sandy in texture and the sub-soil too loose and porous to make farming by the ordinary methods profitable.

Water Supply.—The supply of water from streams and springs in the region of North Dakota west of the Missouri river is much greater than that generally throughout the eastern half of the state. None of the streams west of the Missouri are large except during

(a) CROWN BUTTE.

The occurrence of outcropping ledges of rock on the crests of the hills is common west of the Missouri river. Where erosion is rapid the landscape becomes "bad lands." Where erosion is less active the landscape becomes a grassy, rolling plain.

(b) AN OUTCROPPING LEDGE OF LIGNITE COAL, NEAR SAND CREEK P. O.

The coal seam has been exposed by the erosion of the banks of Sand creek. The seam is estimated to be 40 feet in thickness.

the rainy seasons and times of melting snows. However there is a constant supply of water for stock during the entire year in the larger streams. (Plates XXXVII B; XLI A; XLII A; XLVII A, XLVIII B; L A.) Streams and springs have furnished the water supply for the stock of the ranges during the past, but with the settlement of the country by farmers this supply will be insufficient, and owing to the distances it would be impracticable for the settlers generally to depend upon the water of the streams. Some fine springs furnish excellent water and an abundant supply, but this supply can be only made available to the few who are so fortunately situated as to have access to a spring.

Obviously therefore the question of a water supply from wells is soon bound to become a practical question.

So far as this problem has been solved by the practical test of experience the results seem very favorable and satisfactory. Few tests for artesian water have been made, and the question of artesian or flowing wells is therefore largely an open one, though there seems to be ground to doubt if artesian water will prove to be available in this region generally. However the sandstone layers underlying the country should, and probably do, contain abundant supplies of water, so far as geological deduction gives a clue. Experience in digging wells wherever observations have been made seem to substantiate this view. Good supplies of water are obtained in wells from 25 to 70 feet in depth, so far as records are at hand to show. Nothing like a complete summary of the records of the known diggings has been made by this survey as yet, and the knowledge at hand is limited to the occasional observations made in various parts of the region. These observations lead to the tentative conclusion that there is probably an abundance of water of good quality to be had at depths, as before indicated, of 25 to 70 feet, though it may be found necessary to go to greater depths in some cases. The water should be good, based on geological evidence, for it is almost always the case that water that is derived from sand or gravel beds is of good quality, often soft, and generally free from alkali or other undesirable mineral substances.

Fuel.—Western North Dakota is abundantly blessed in the matter of natural fuel supply. It is probably not an overestimate to say that there is reasonable assurance, based upon geological investigations, that coal seams underlie practically all of the region west of the Missouri river and, not only this, but it is so situated that mines

can be operated almost anywhere. (Plates XXXIII, B; XLIX, B.) There are scores and hundreds of outcroppings of lignite coal of good quality that have never been touched by way of development simply because there are so many accessible openings, so many workable mines distributed wherever there is a demand for coal. Many farmers own their own coal mines, just as in the eastern states farmers own a "wood lot."

Coal can be had in hundreds of places for the mere labor of mining. In other cases farmers drive to the mine, have their wagons filled, and then haul home their supply, paying perhaps $1.00 per ton for the coal loaded at the mine. Or it can be purchased delivered for a price that merely pays for the mining and hauling.

Lignite coal burns without the smoke, soot, and disagreeable blackening that accompanies the use of the bituminous coals of the Mississippi valley. A supply of fuel for a North Dakota winter costs not to exceed one-fifth of what it costs for southern Minnesota, Iowa, or Wisconsin winter.

Transportation.—One of the most serious hindrances to the successful development of the great region west of the Missouri river at present is the problem of transportation of farm products and accessibility of local markets. At the present time the counties of Hettinger, Oliver, Mercer, Dunn, McKenzie, and Bowman are without railroad facilities, and the result is a long and tedious journey to and from local markets. (See Plate L B.)

There is reason to believe that in the near future better railroad facilities will be afforded. As soon as there are products to be transported and supplies to be brought in, as demanded by an increased population, a natural result would be that roalroads would seek these avenues of business. Already several surveys have been made in various parts of the vast region west of the Missouri river, and it may confidently be predicted that soon there will be lines of railroad traversing these broad and fertile lands.

(a) SPRING, AT SCHAFER.

is one of the finest springs in the northwest. The water is clear, cold and pure. ιes out of the hillside in the valley of Cherry creek.

(b) NOTHING LIKE THE HORSE AFTER ALL!

machine was 40 miles from railroad when it went out of business. The Williston ırveying party were the good Samaritans.

INDEX